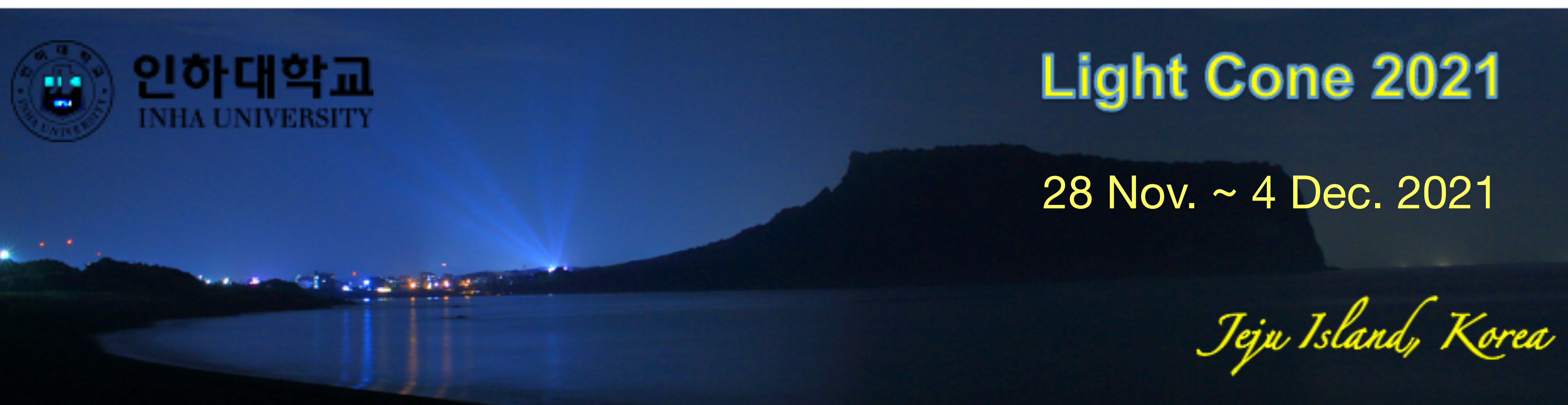
The axial-vector transitions between the singly charmed baryons within a mesonic mean-field approach

Yuson Jun[1]

Collaborating with Jungmin Suh[1], Hyun-Chul Kim[1,2]

[1]*Department of Physics, Inha University*
[2]*School of Physics, Korea Institute for Advanced Study (KIAS)*



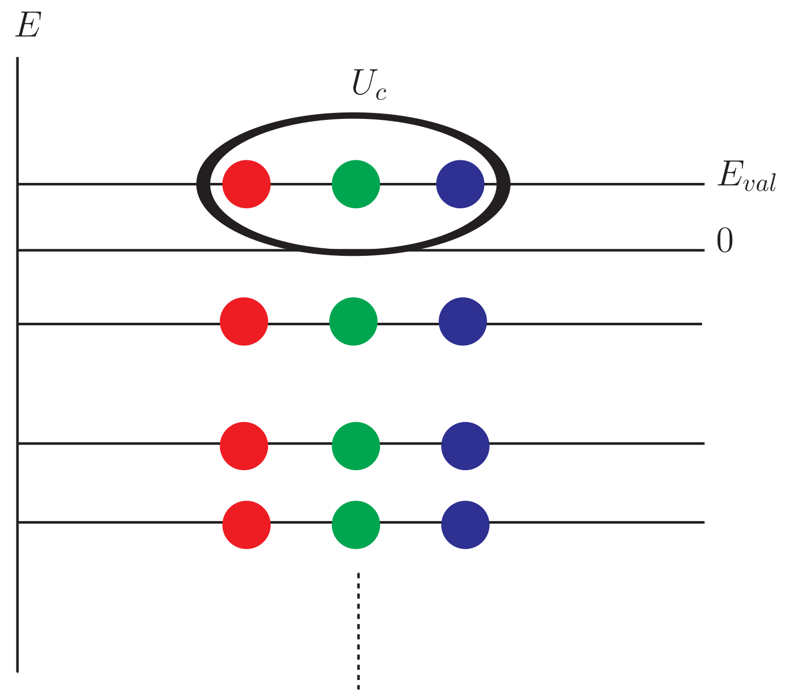
Contents

- Introduction
- Chiral quark-soliton model
- Matrix element of the axial-vector current
- Axial-vector transition form factors of the singly charmed baryons
- Summary & Outlook

Introduction

- Transitions between the singly charmed baryons have been explored for several decades.
- The axial-vector transition form factors between different representations were not much studied.
- In this work, we investigate the axial-vector transition form factors between the charmed baryon sextet and baryon anti-triplet within the framework of the chiral quark-soliton model.

The chiral quark-soliton model

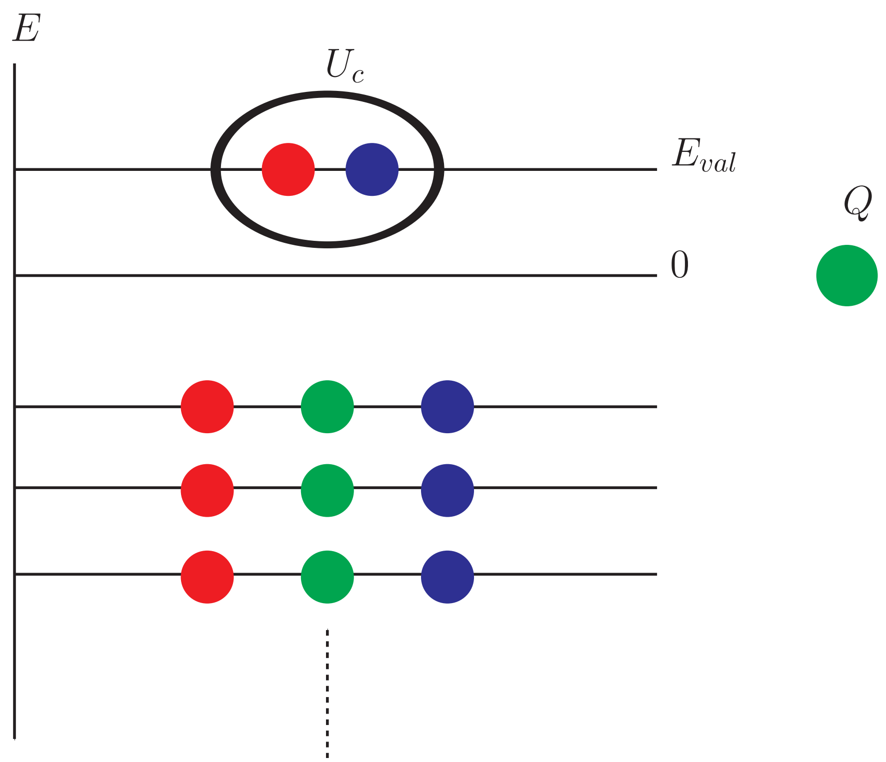


- Baryons can be considered as states of the Nc valence quarks bound by the mesonic mean-fields at large Nc
(E. Witten, NPB160, 57, 1979).

$$S_{\text{eff}}(U) = -N_c \text{Tr} \ln \left[\partial_\tau + h(U) - i\gamma_4 \delta m\right]$$ **Effective chiral action**

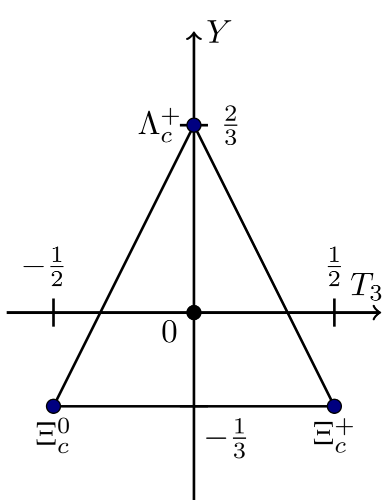
- Red part: one-particle Dirac hamiltonian with the pion mean-field.
- Blue part: The flavor SU(3) symmetry-breaking contribution.
- In this work, we consider the rotational 1/Nc corrections and the effects of the breaking of flavor SU(3) symmetry.

The chiral quark-soliton model

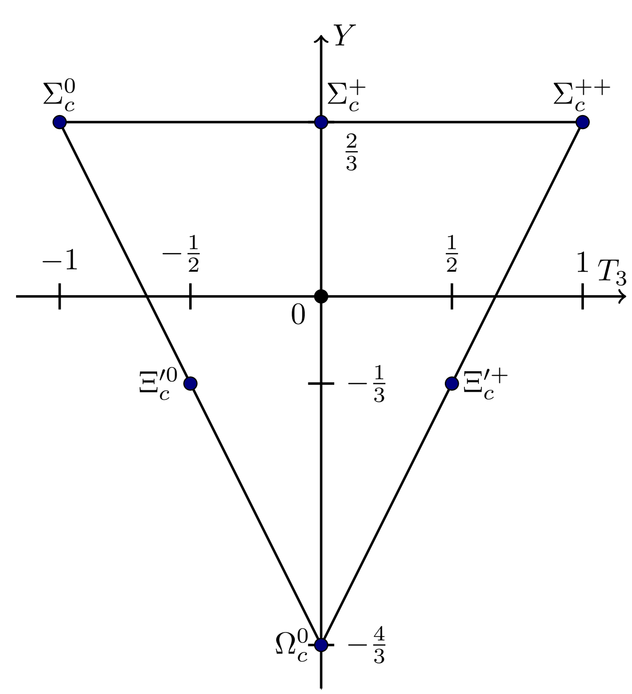


- Nc valence quarks change into Nc-1 valence quarks
- Heavy quark considered as a static color source.
- Heavy quark does not contribute to the transition form factors [1,2].

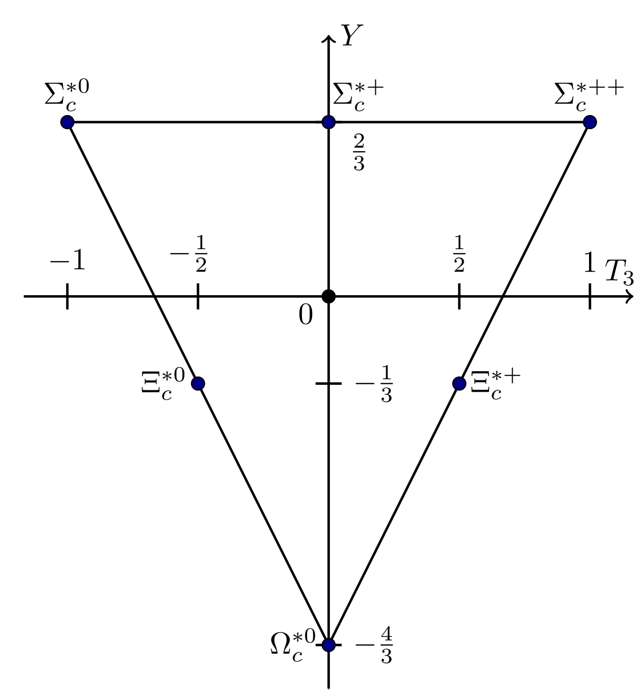
[1] P. Cho, H. Georgi, PLB 296, 408 (1992)
[2] H.-Y. Cheng et al, PRD 46, 5060 (1992)



Anti-triplet, J=1/2

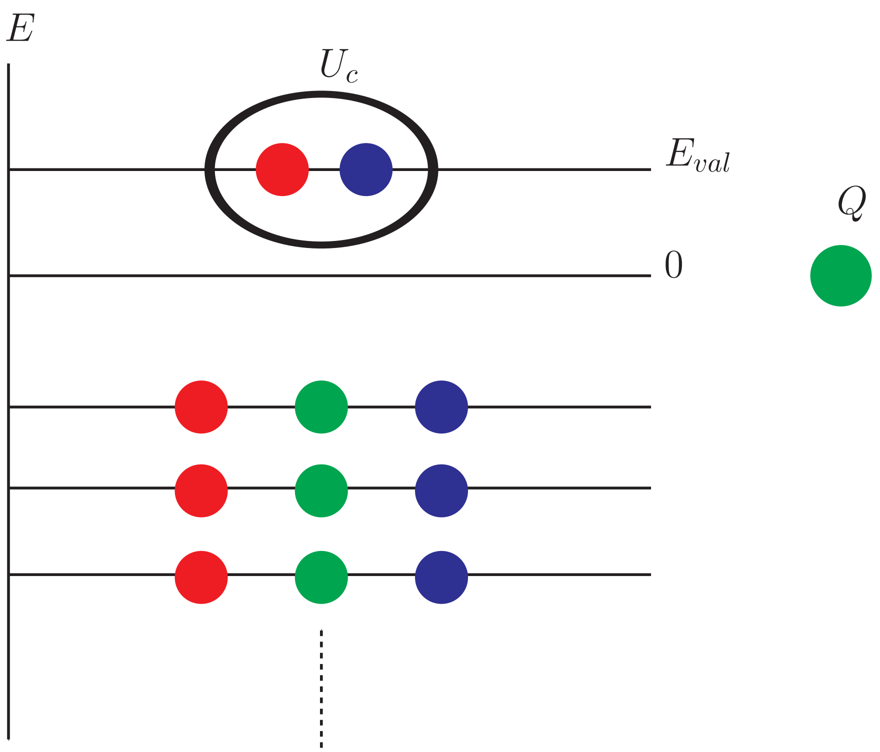


Sextet, J=1/2



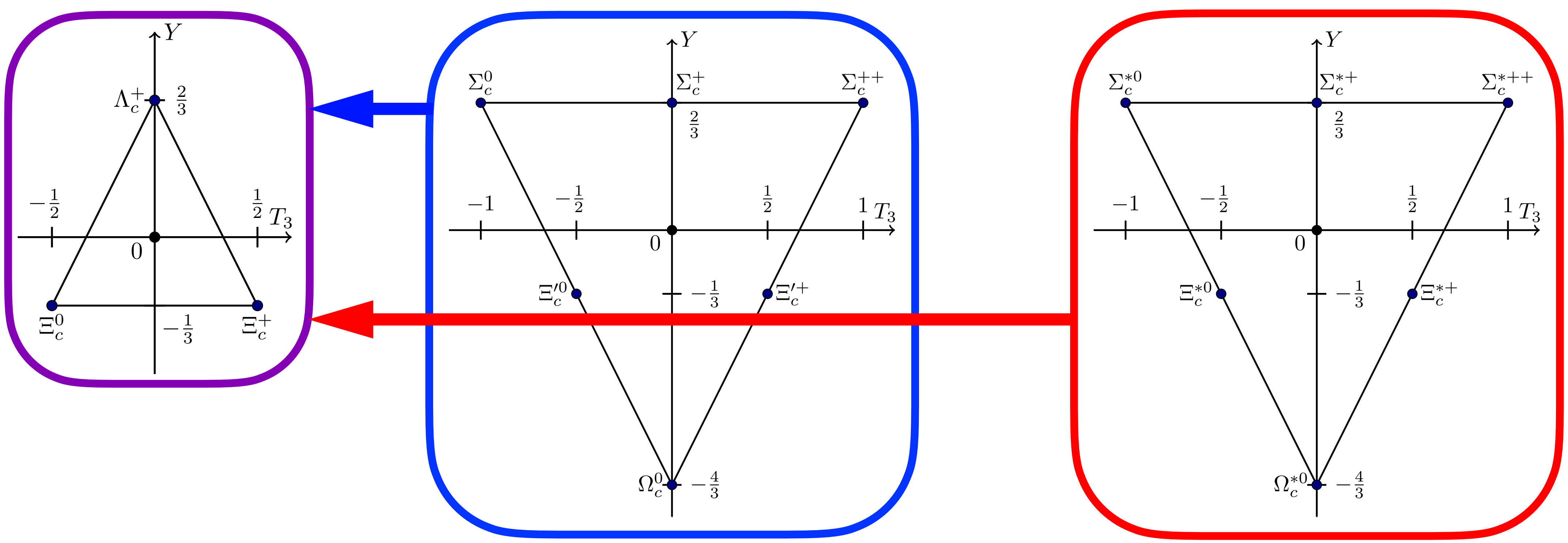
Sextet, J=3/2

The chiral quark-soliton model



- Nc valence quarks change into Nc-1 valence quarks
- Heavy quark considered as a static color source.
- Heavy quark does not contribute to the transition form factors [1,2].

[1] P. Cho, H. Georgi, PLB 296, 408 (1992)
[2] H.-Y. Cheng et al, PRD 46, 5060 (1992)



Anti-triplet, J=1/2 **Sextet, J=1/2** **Sextet, J=3/2**

Matrix element of the axial-vector current

$$\langle B'_{J'_3} | A^a_\mu(0) | B_{J_3} \rangle \qquad A^a_\mu(x) = \overline{\psi}(x)\gamma_\mu\gamma_5\frac{\lambda^a}{2}\psi(x) + \overline{\Psi}(x)\gamma_\mu\gamma_5\Psi(x)$$

J=1/2 to J=1/2 case:

$$\overline{u}(p', J'_3)\left[g_A^{(a)}(Q^2)\gamma_\mu + \frac{g_P^{(a)}(Q^2)}{M'+M}Q_\mu\right]\frac{\gamma_5}{2}u(p, J_3)$$

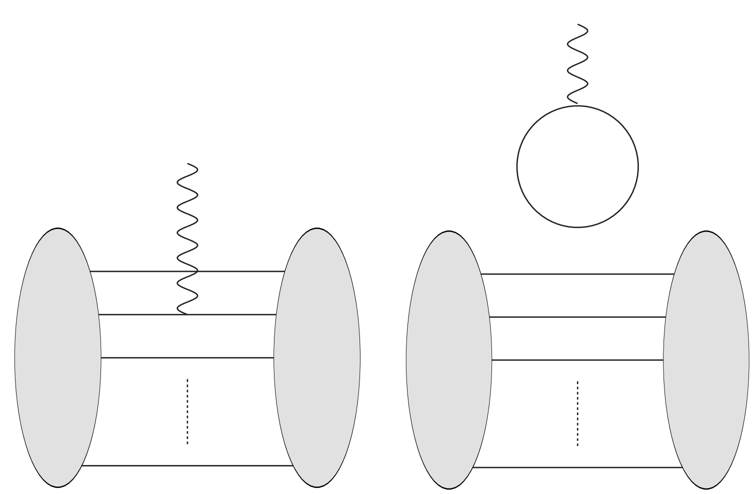
J=3/2 to J=1/2 case[3]: [3] S. L. Adler, Ann. Phys. 50, 189 (1968); PRD 12, 2644 (1975)

$$\overline{u}(p', J'_3)\left[\left\{\frac{C_3^{A(a)}(Q^2)}{M'}\gamma^\nu + \frac{C_4^{A(a)}(Q^2)}{M'^2}p^\nu\right\}(g_{\alpha\mu}g_{\rho\nu} - g_{\alpha\rho}g_{\mu\nu}) + C_5^{A(a)}(Q^2)g_{\alpha\mu} + \frac{C_6^{A(a)}(Q^2)}{M'^2}Q_\alpha Q_\mu\right]u^\alpha(p, J_3)$$

In the model:

$$\int dA \int d^3r e^{i\vec{Q}\cdot\vec{r}} \langle B'_{J'_3} | A\rangle \left[\mathscr{F}^a_{\mathrm{val},\mu}(\vec{r}, A) + \mathscr{F}^a_{\mathrm{sea},\mu}(\vec{r}, A)\right] \langle A | B_{J_3}\rangle$$

Valence-quark contribution



Sea-quark contribution

Matrix element of the axial-vector current

$$\langle B'_{J'_3} | A^a_\mu(0) | B_{J_3} \rangle \qquad A^a_\mu(x) = \overline{\psi}(x)\gamma_\mu\gamma_5 \frac{\lambda^a}{2}\psi(x) + \overline{\Psi}(x)\gamma_\mu\gamma_5\Psi(x)$$

J=1/2 to J=1/2 case:

$$\overline{u}(p', J'_3)\left[g_A^{(a)}(Q^2)\gamma_\mu + \frac{g_P^{(a)}(Q^2)}{M'+M}Q_\mu \right]\frac{\gamma_5}{2}u(p, J_3)$$

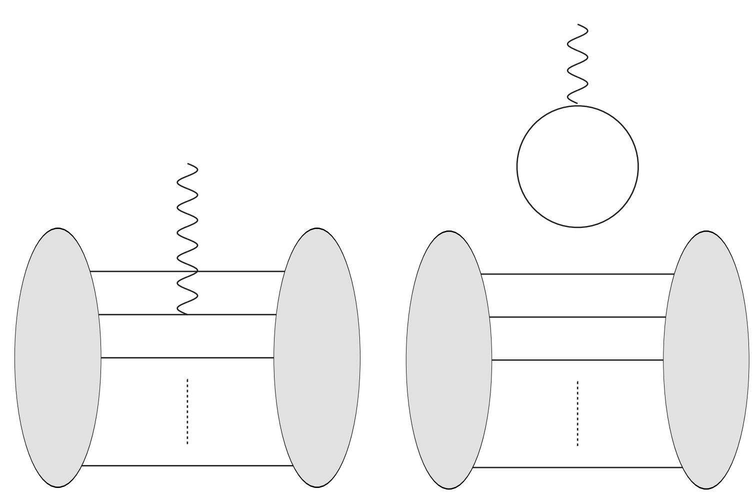
J=3/2 to J=1/2 case[3]: [3] S. L. Adler, Ann. Phys. 50, 189 (1968); PRD 12, 2644 (1975)

$$\overline{u}(p', J'_3)\left[\left\{ \frac{C_3^{A(a)}(Q^2)}{M'}\gamma^\nu + \frac{C_4^{A(a)}(Q^2)}{M'^2}p^\nu \right\}(g_{\alpha\mu}g_{\rho\nu} - g_{\alpha\rho}g_{\mu\nu}) + C_5^{A(a)}(Q^2)g_{\alpha\mu} + \frac{C_6^{A(a)}(Q^2)}{M'^2}Q_\alpha Q_\mu \right] u^\alpha(p, J_3)$$

In the model:

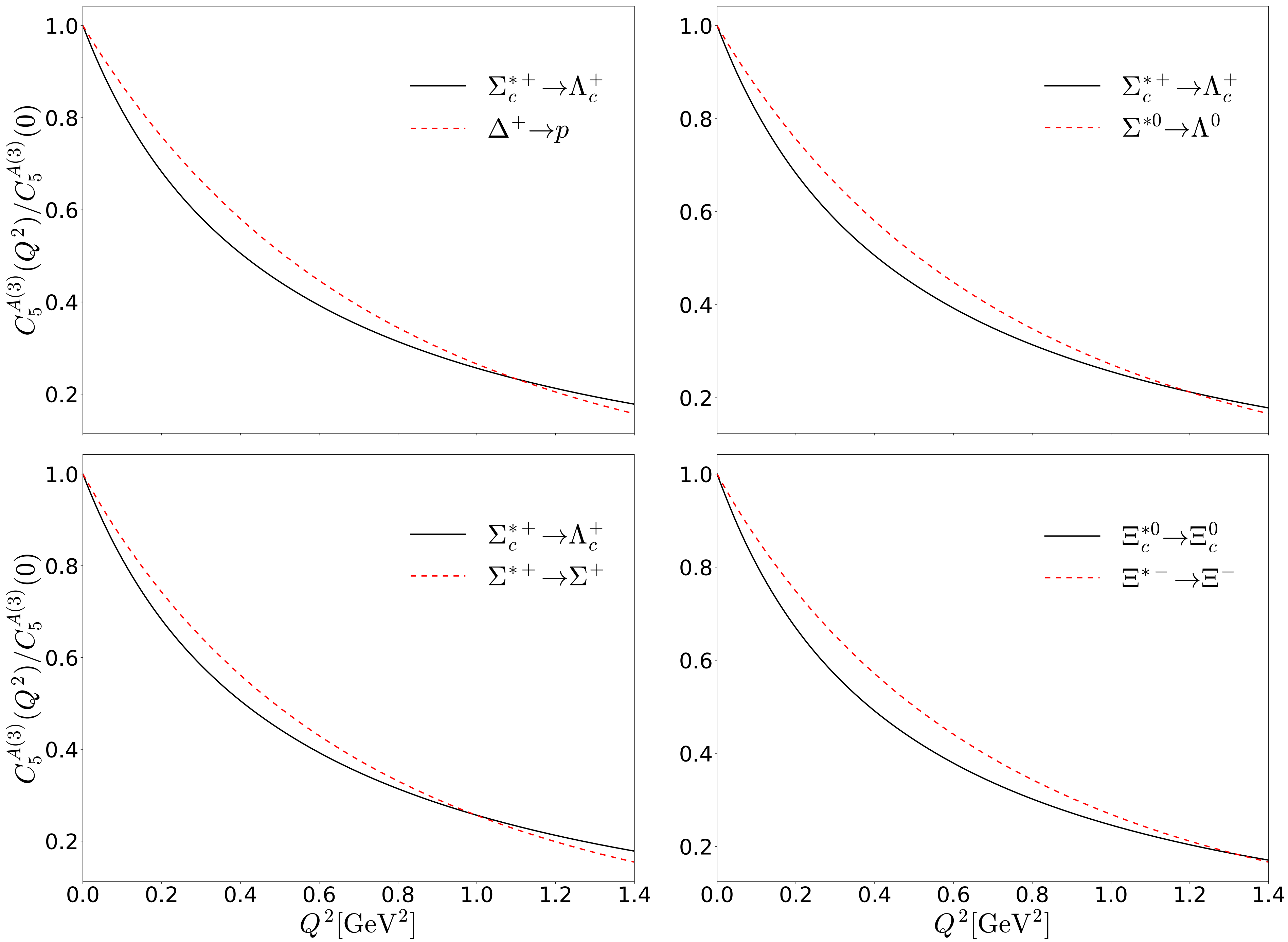
$$\int dA \int d^3r e^{i\vec{Q}\cdot\vec{r}} \langle B'_{J'_3} | A \rangle \left[\mathscr{F}^a_{\mathrm{val},\mu}(\vec{r}, A) + \mathscr{F}^a_{\mathrm{sea},\mu}(\vec{r}, A) \right] \langle A | B_{J_3} \rangle$$

Valence-quark contribution



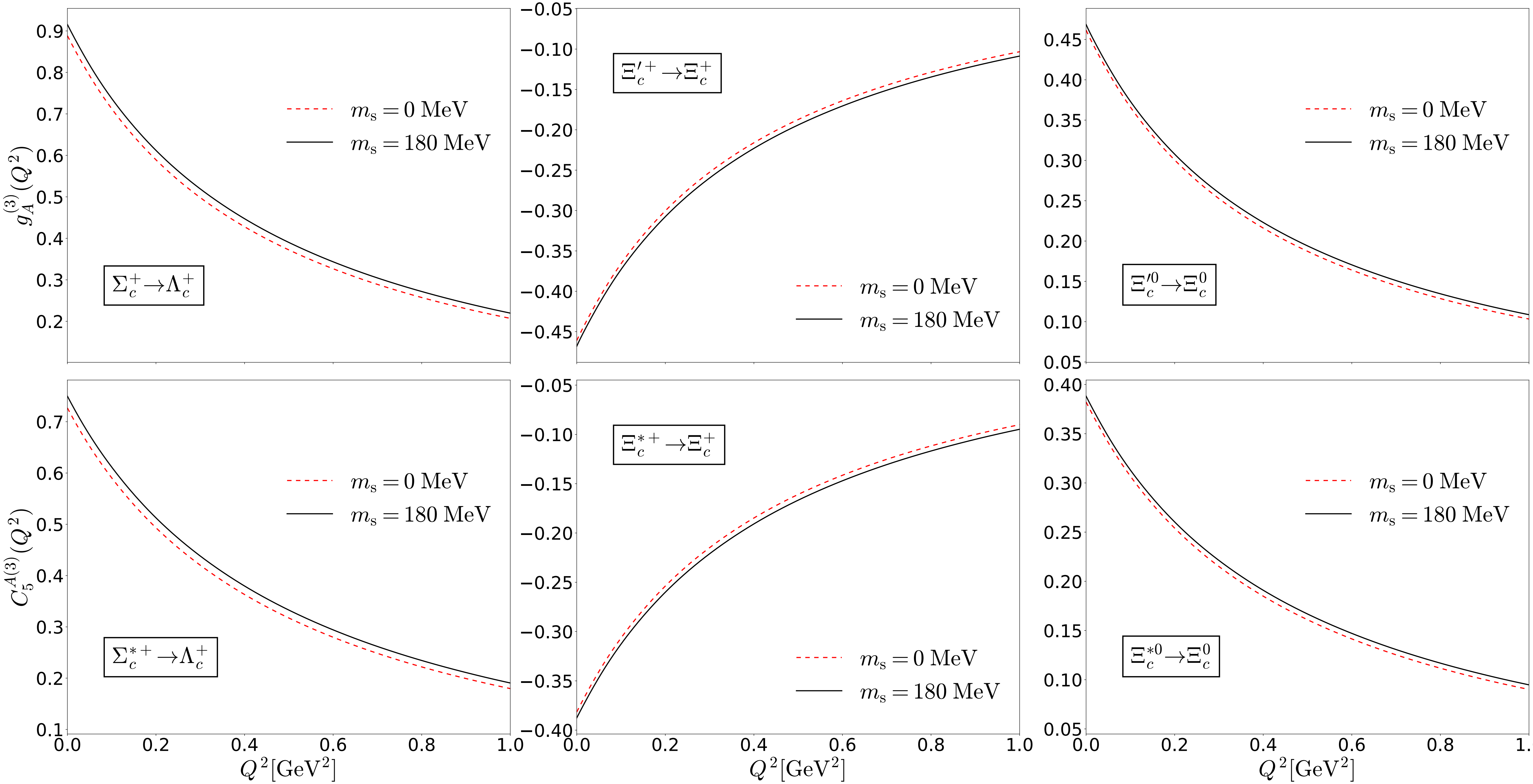
Sea-quark contribution

Axial-vector transition form factor for the singly heavy baryons comparison with those of the light baryons



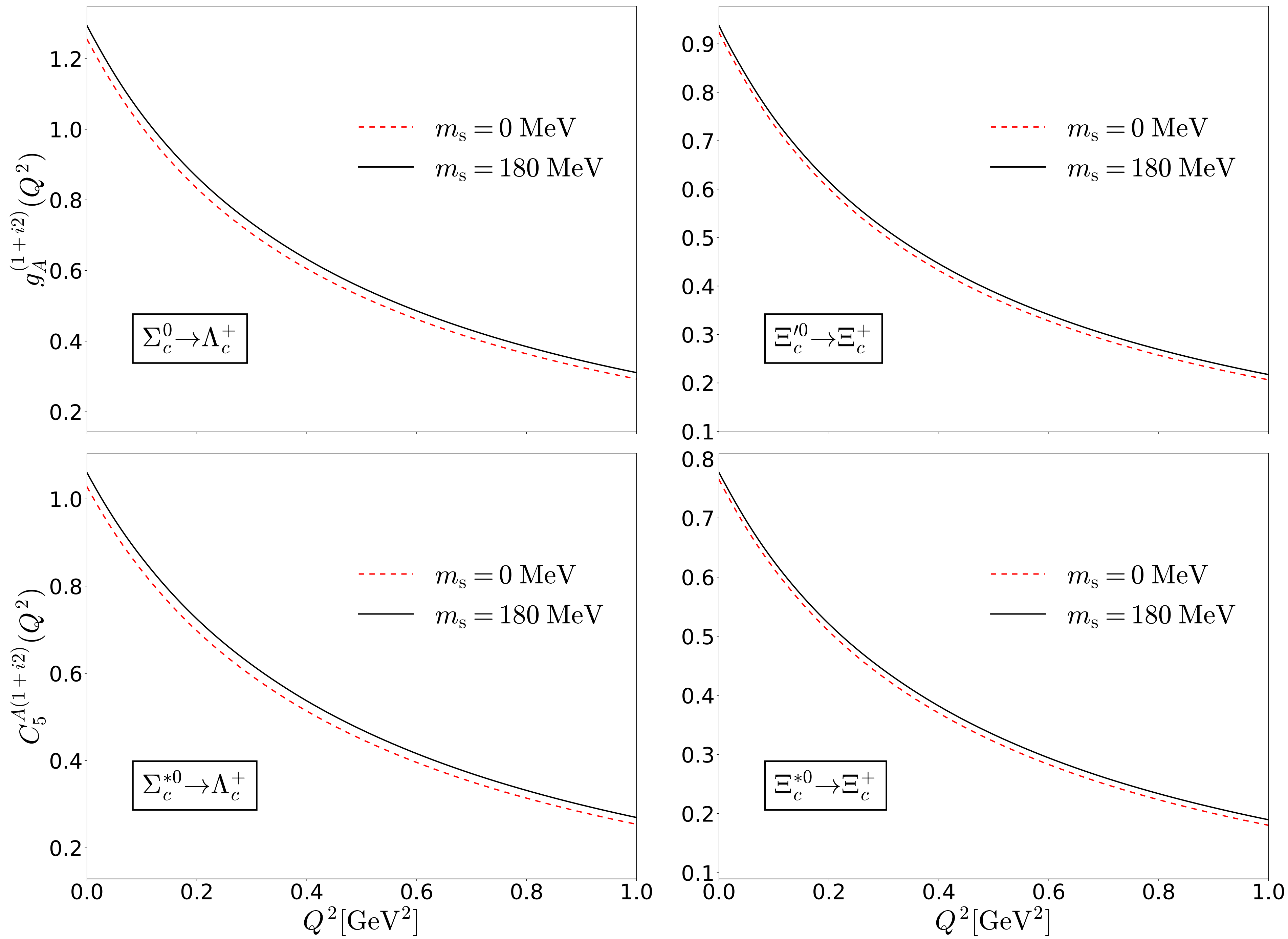
$\Delta S = 0$ **and** $\Delta Q = 0$ **Transition processes**

Axial-vector transition form factors of the singly charmed baryons(The $SU(3)_f$ - Sym. Breaking effects)



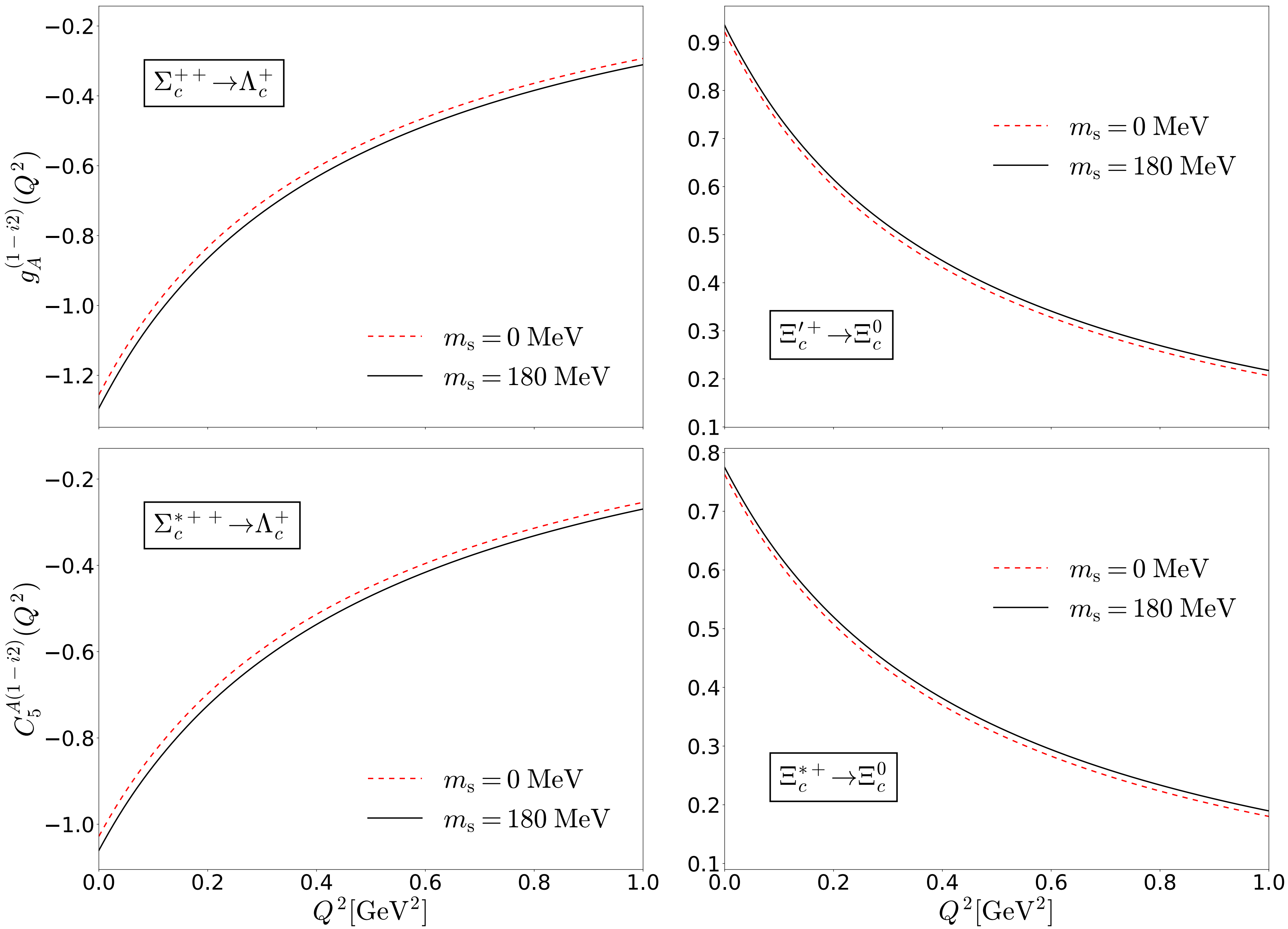
$\Delta S = 0$ and $\Delta Q = 0$ Transition processes

Axial-vector transition form factors of the singly charmed baryons(The $SU(3)_f$ - Sym. Breaking effects)



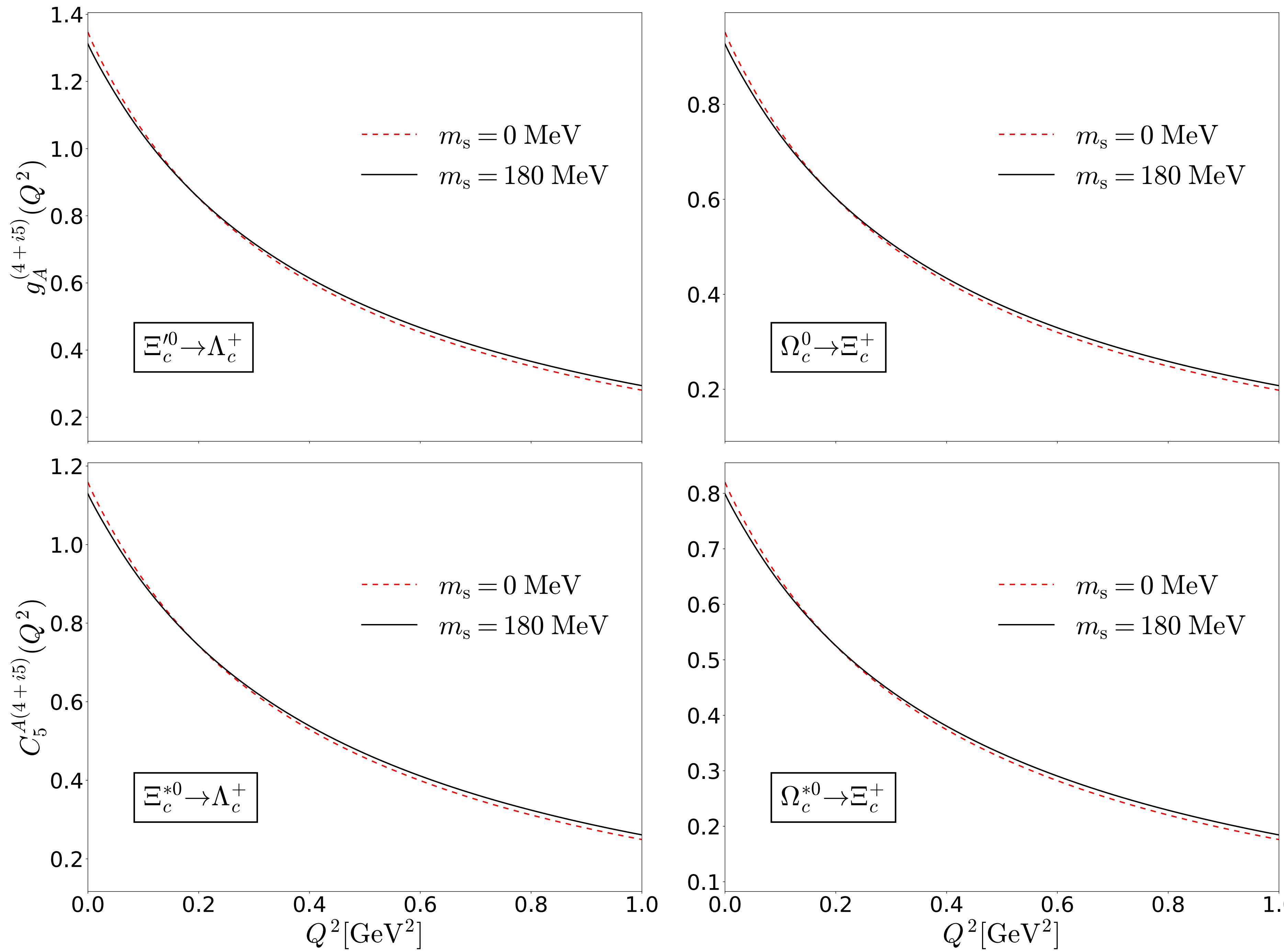
$\Delta S = 0$ **and** $\Delta Q = 1$ **Transition processes**

Axial-vector transition form factors of the singly charmed baryons(The $SU(3)_f$ - Sym. Breaking effects)



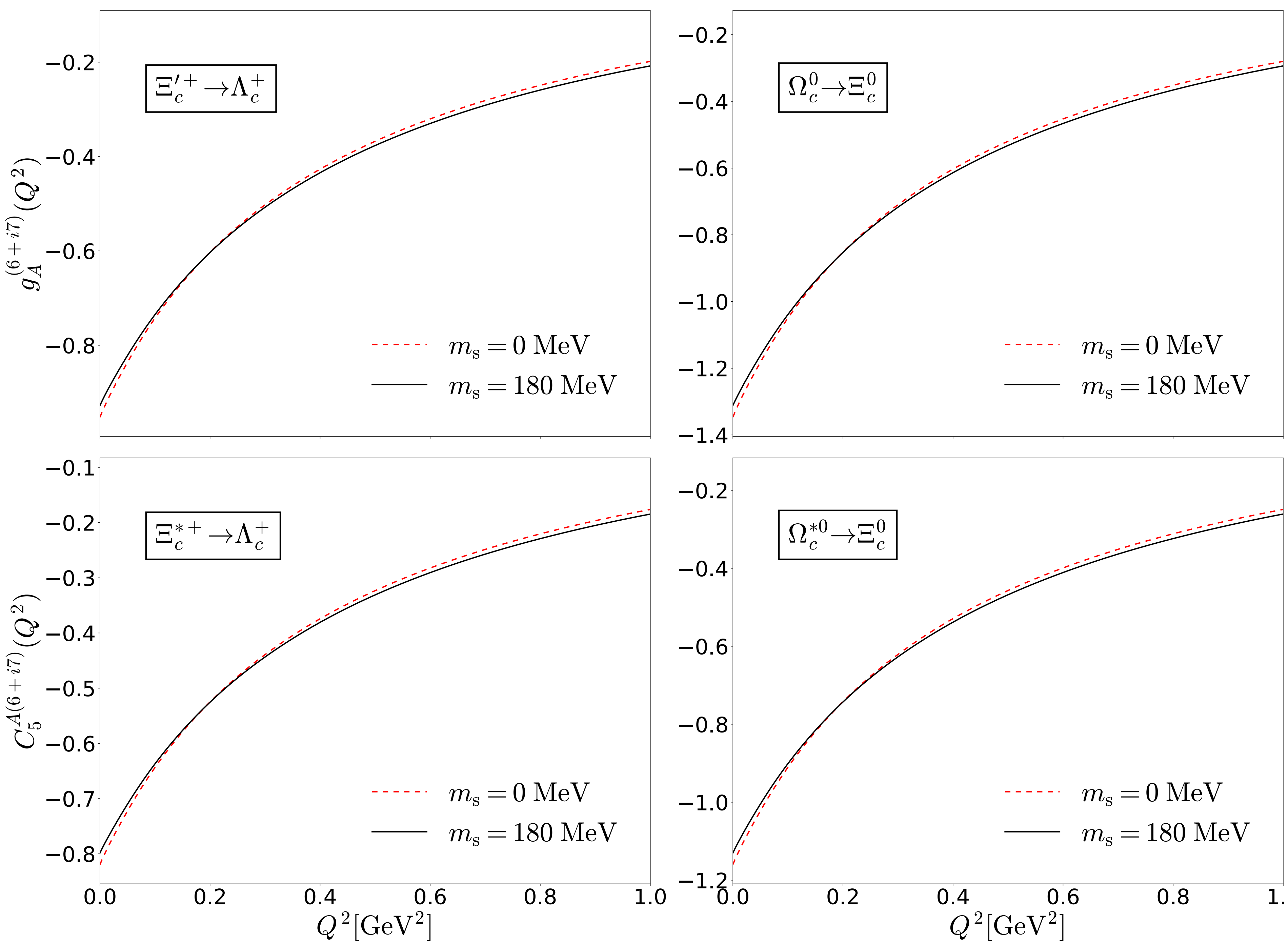
$\Delta S = 0$ and $\Delta Q = -1$ Transition processes

Axial-vector transition form factors of the singly charmed baryons(The $SU(3)_f$ - Sym. Breaking effects)



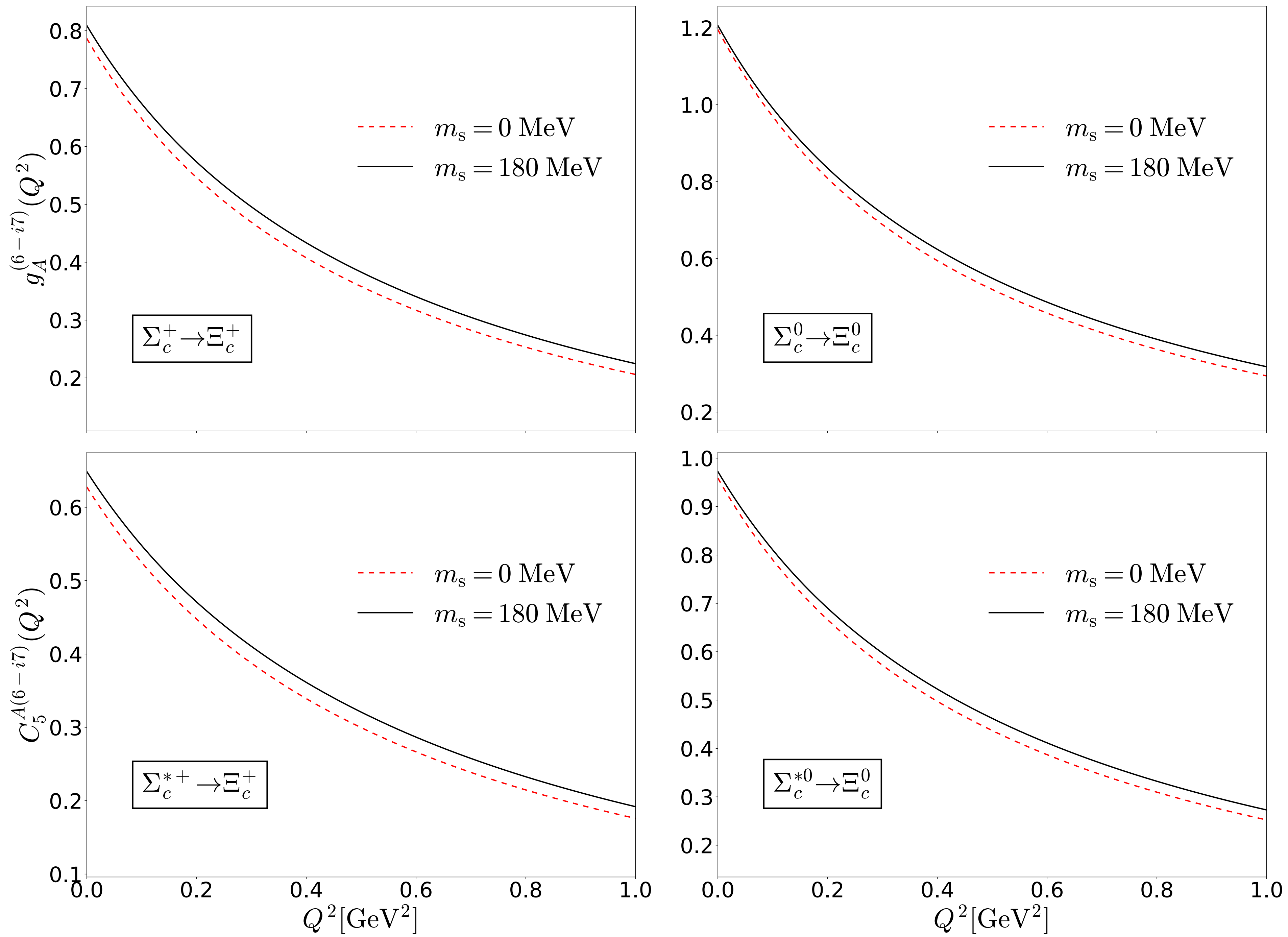
$\Delta S = 1$ and $\Delta Q = 1$ Transition processes

Axial-vector transition form factors of the singly charmed baryons(The $SU(3)_f$ - Sym. Breaking effects)



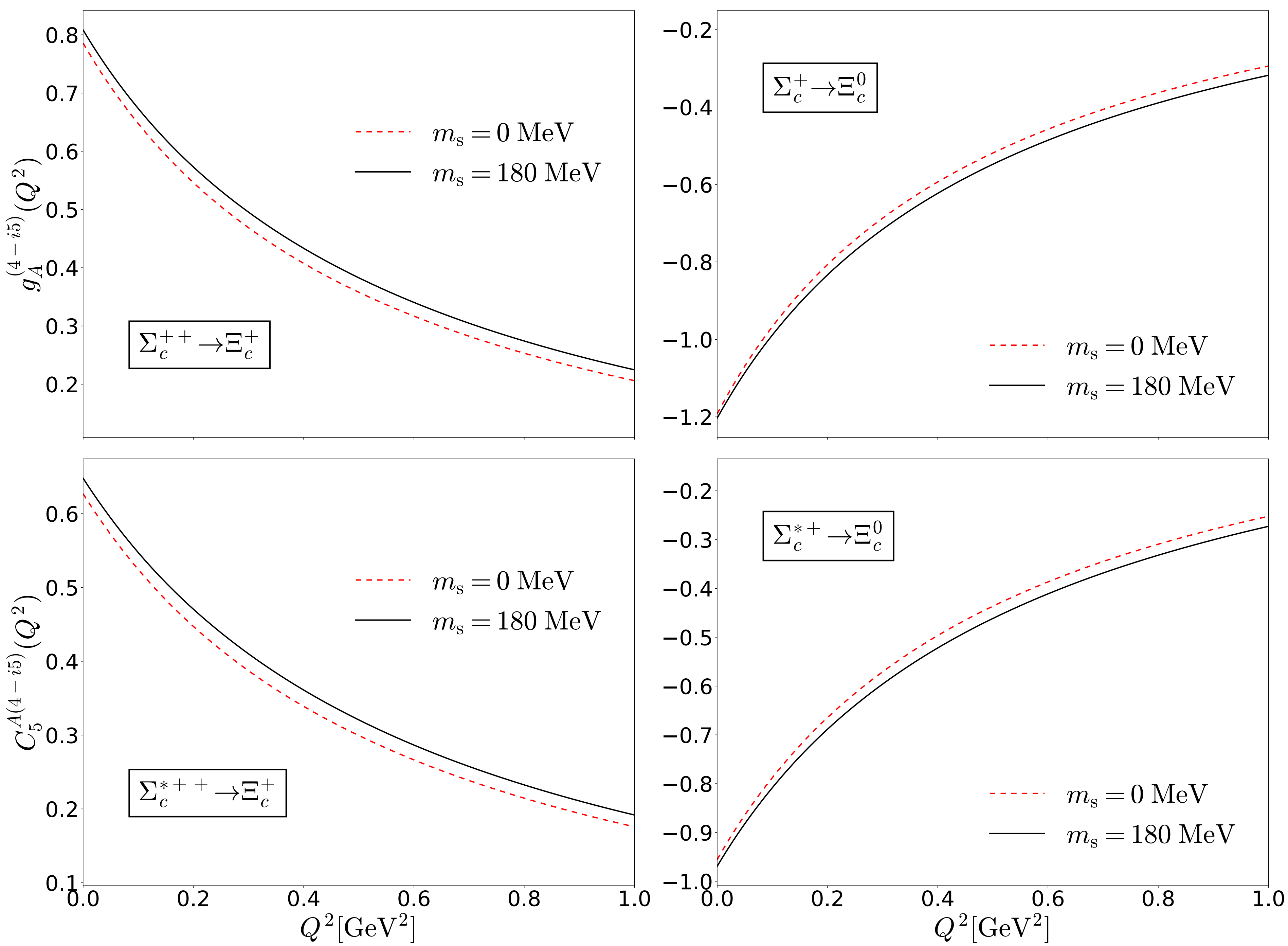
$\Delta S = 1$ **and** $\Delta Q = 0$ **Transition processes**

Axial-vector transition form factors of the singly charmed baryons(The $SU(3)_f$ - Sym. Breaking effects)



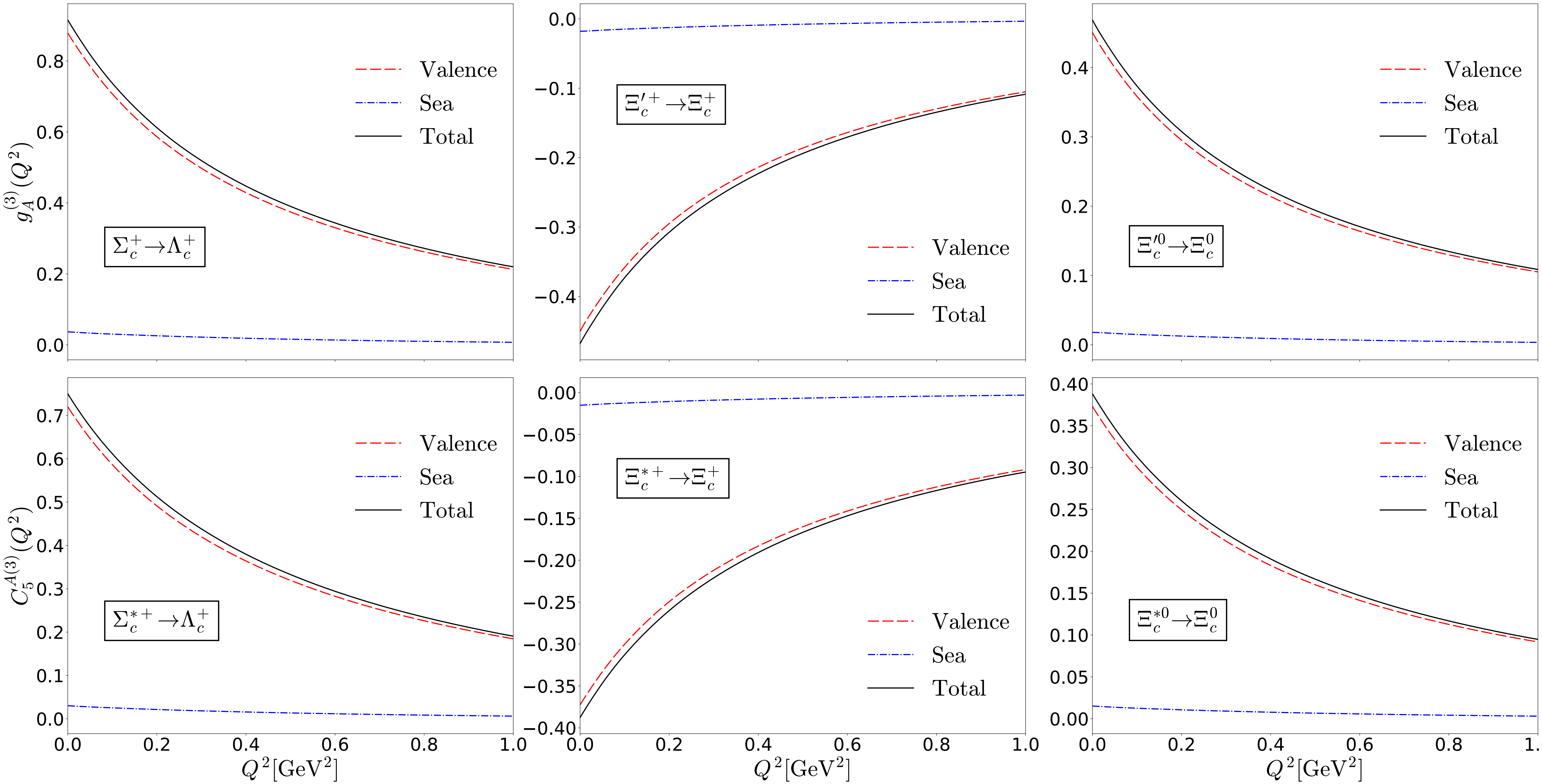
$\Delta S = -1$ and $\Delta Q = 0$ Transition processes

Axial-vector transition form factors of the singly charmed baryons(The $SU(3)_f$ - Sym. Breaking effects)



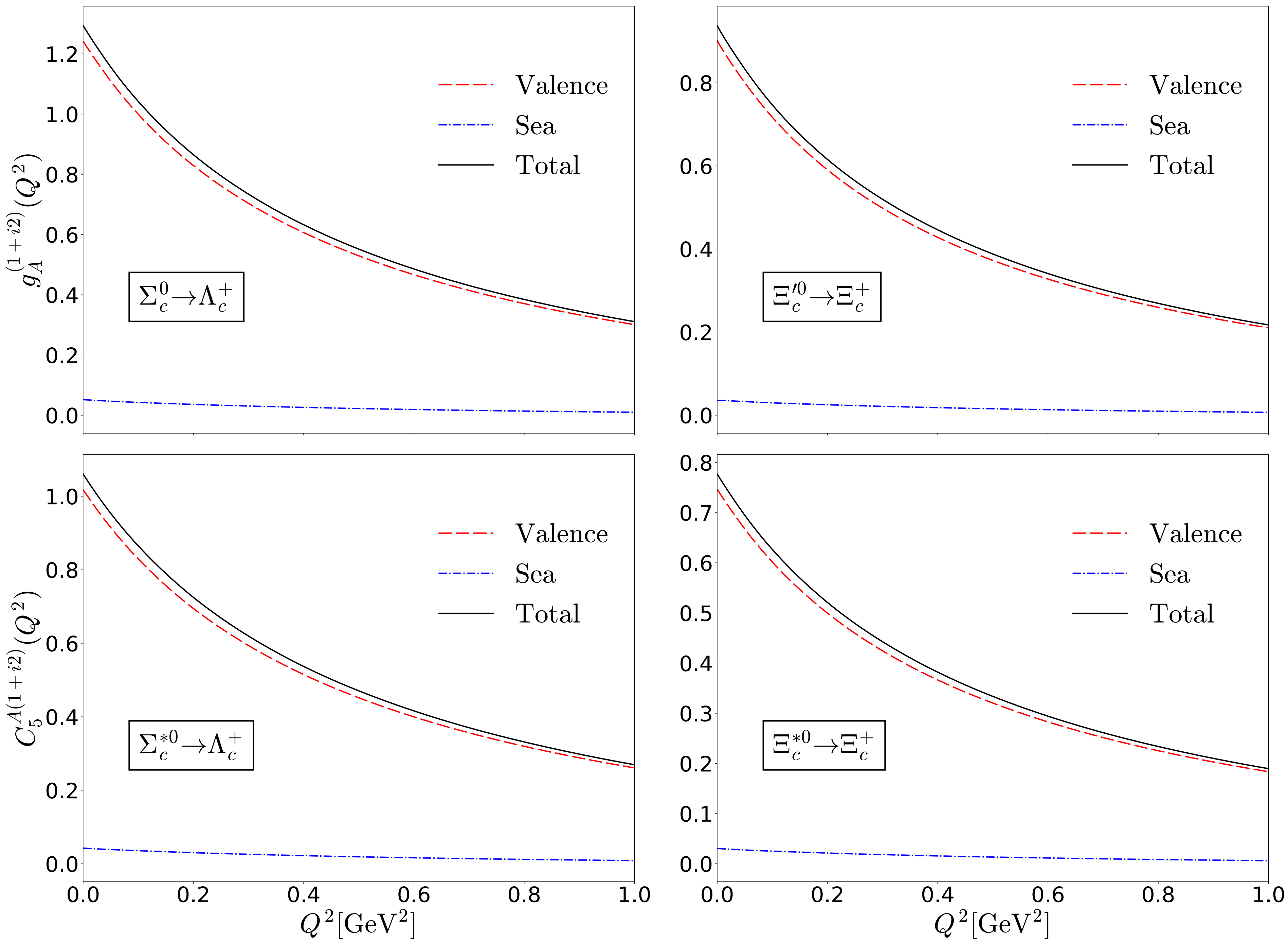
$\Delta S = -1$ and $\Delta Q = -1$ Transition processes

Axial-vector transition form factors of the singly charmed baryons(the valence- and sea-quark contributions)



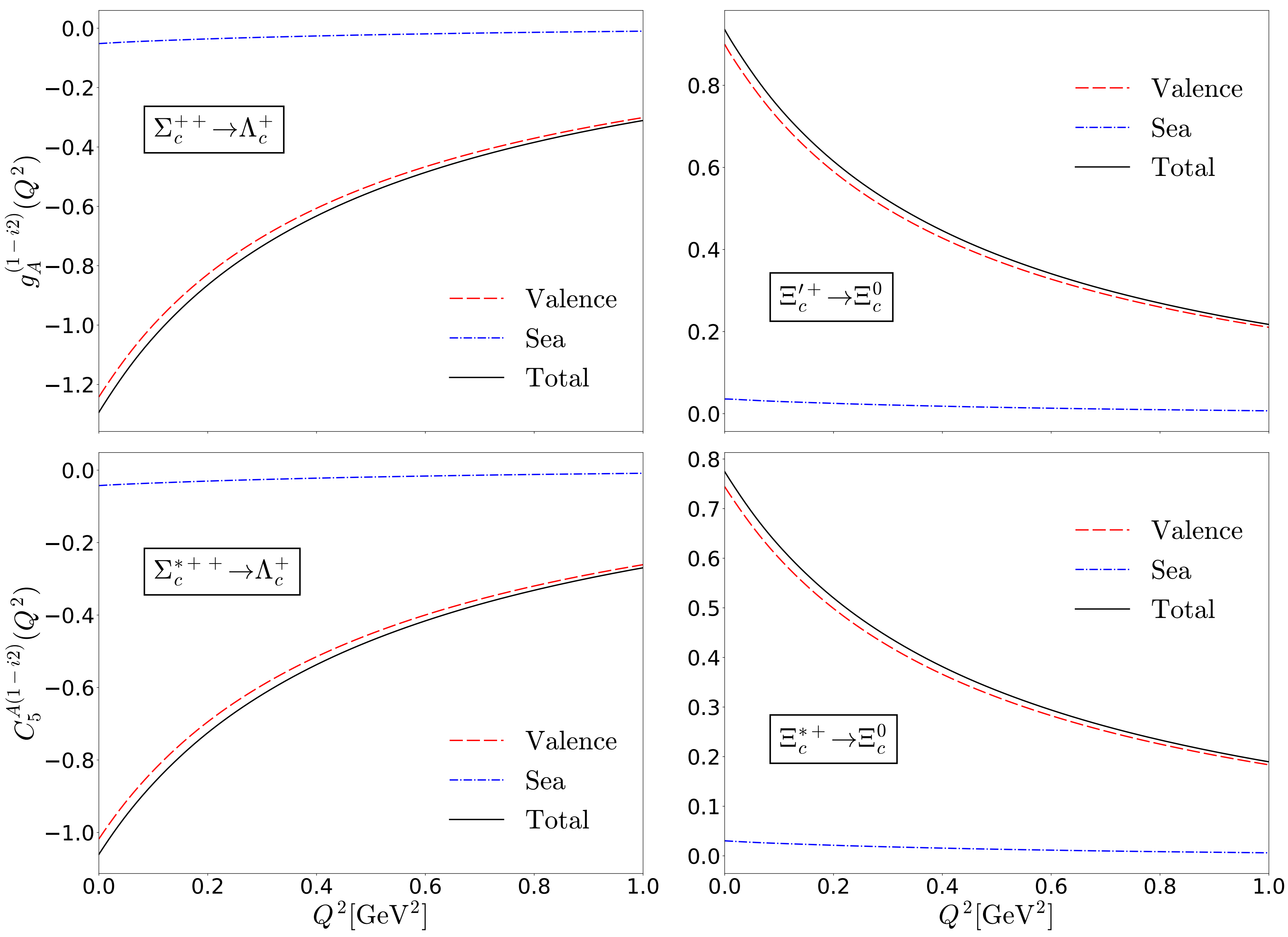
$\Delta S = 0$ **and** $\Delta Q = 0$ **Transition processes**

Axial-vector transition form factors of the singly charmed baryons(the valence- and sea-quark contributions)



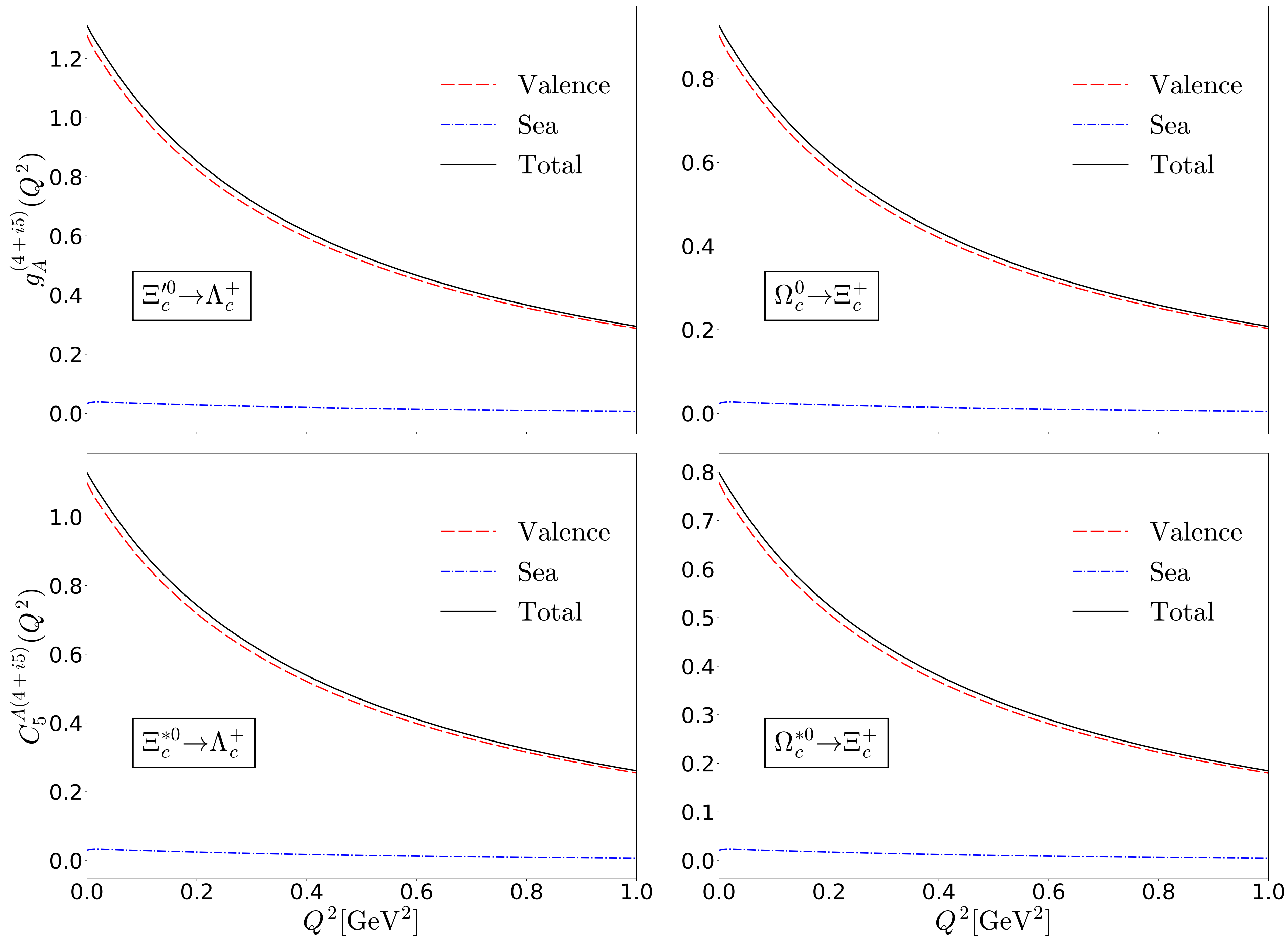
$\Delta S = 0$ and $\Delta Q = 1$ Transition processes

Axial-vector transition form factors of the singly charmed baryons(the valence- and sea-quark contributions)



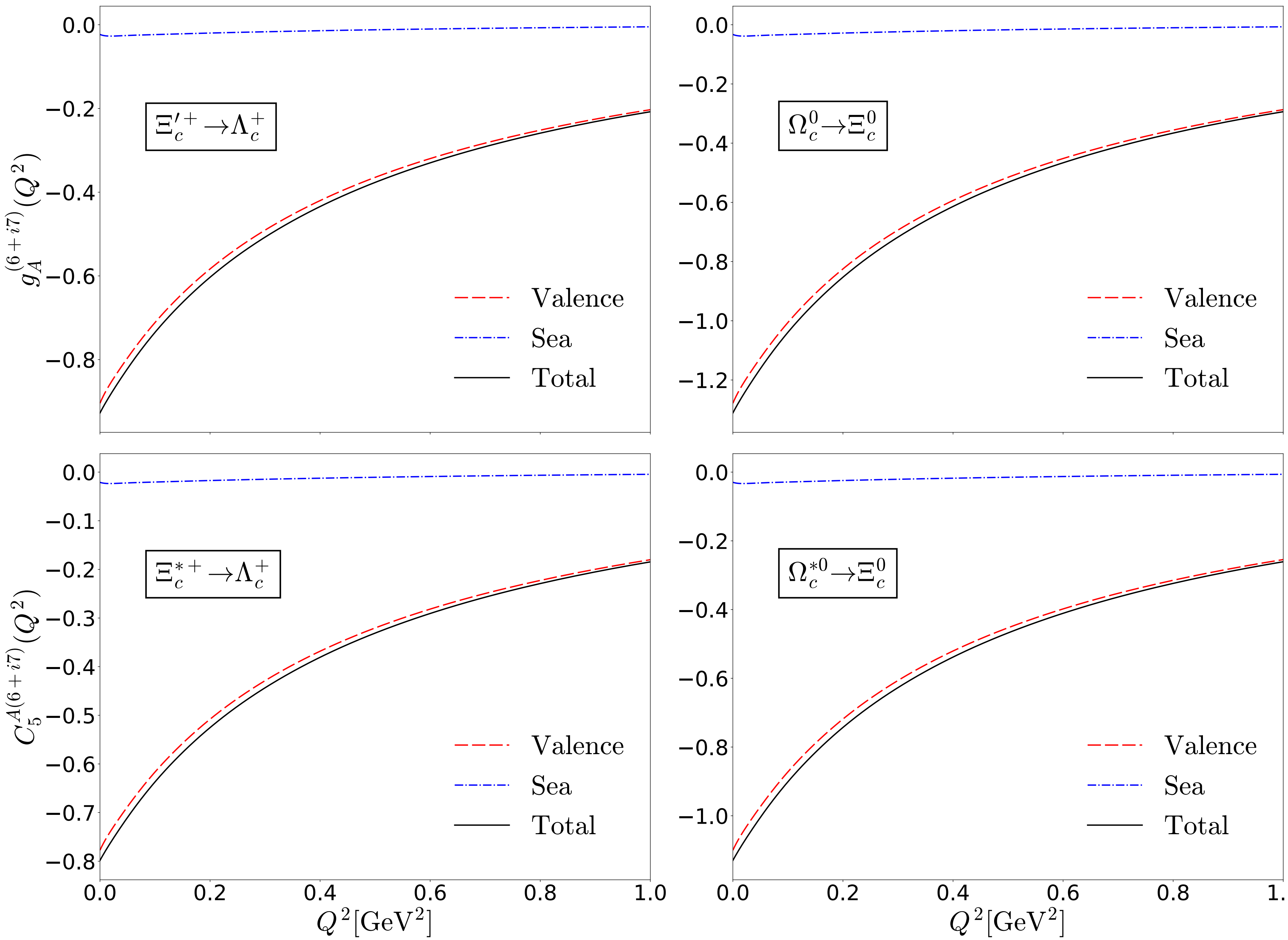
$\Delta S = 0$ and $\Delta Q = -1$ Transition processes

Axial-vector transition form factors of the singly charmed baryons(the valence- and sea-quark contributions)



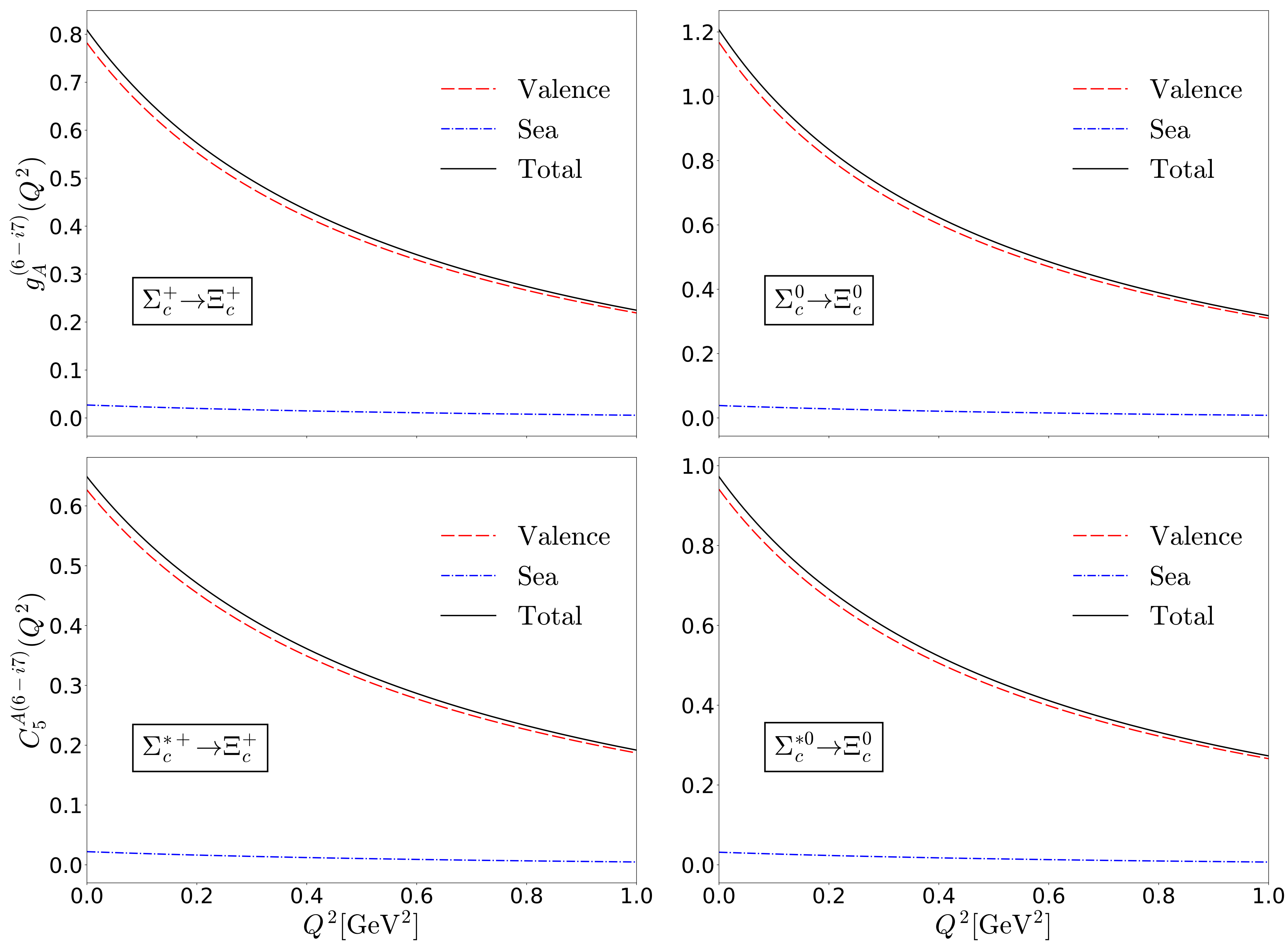
$\Delta S = 1$ **and** $\Delta Q = 1$ **Transition processes**

Axial-vector transition form factors of the singly charmed baryons(the valence- and sea-quark contributions)



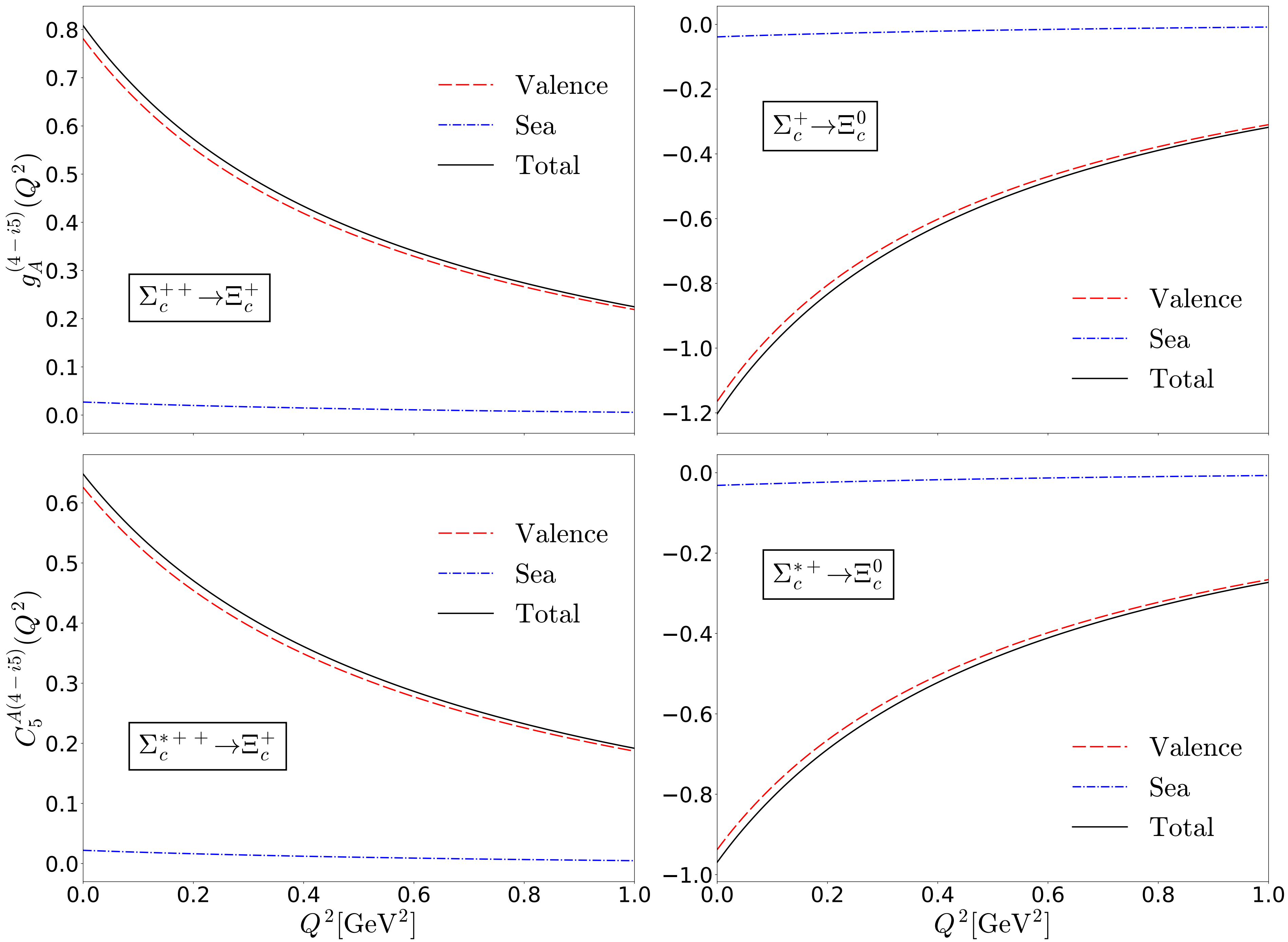
$\Delta S = 1$ **and** $\Delta Q = 0$ **Transition processes**

Axial-vector transition form factors of the singly charmed baryons(the valence- and sea-quark contributions)



$\Delta S = -1$ and $\Delta Q = 0$ Transition processes

Axial-vector transition form factors of the singly charmed baryons(the valence- and sea-quark contributions)



$\Delta S = -1$ **and** $\Delta Q = -1$ **Transition processes**

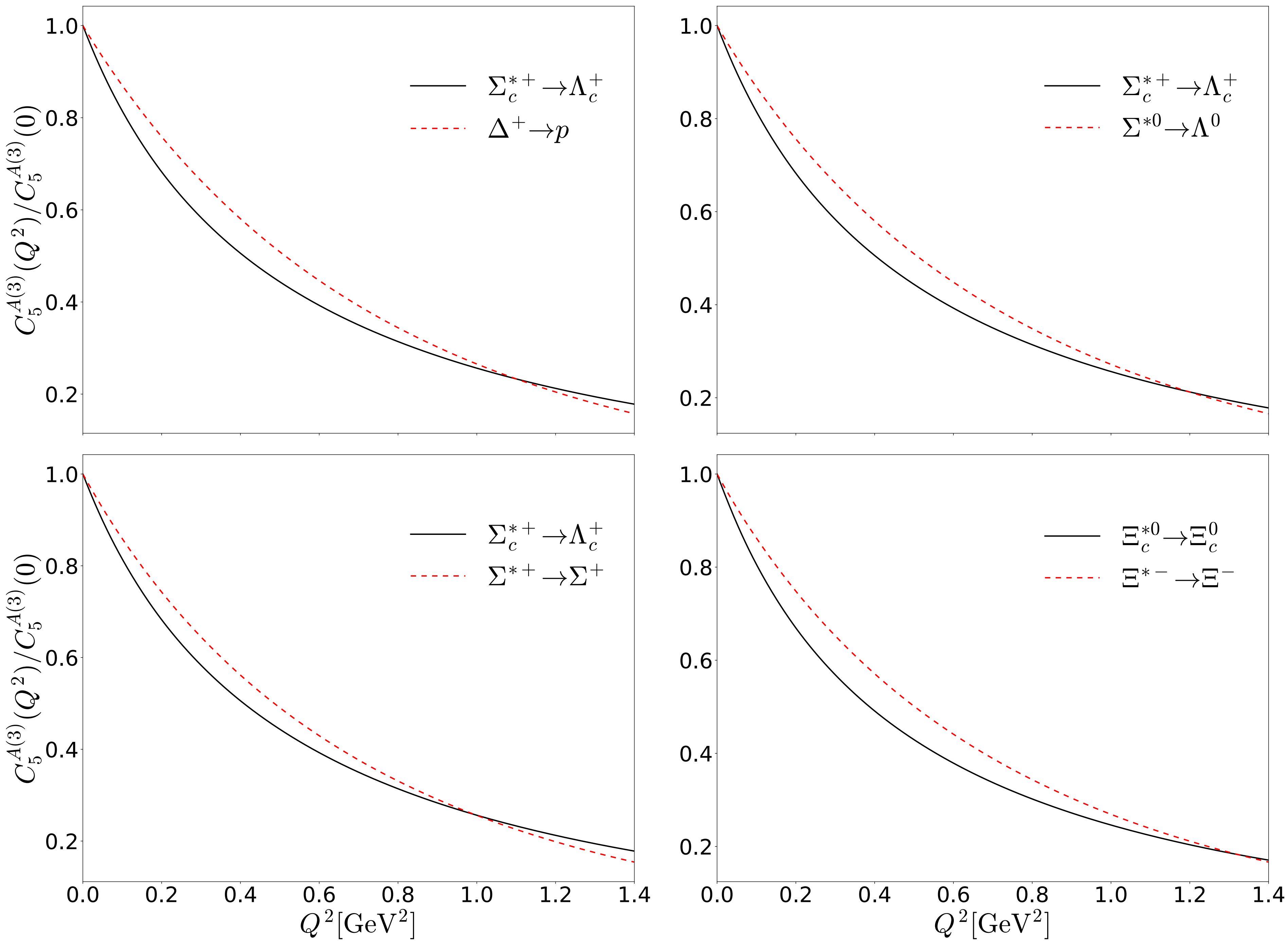
Summary & Outlook

- Summary
  - We studied the axial-vector transition form factors of the singly charmed baryons within the framework of the chiral quark-soliton model.
  - The effects of the flavor SU(3) symmetry breaking are rather small($\lesssim$ 4%).
  - The valence-quark contributions dominate over those from the sea quarks($\gtrsim$ 96%).
- Outlook
  - Transitions between the singly bottom baryons.
  - Transitions between the doubly heavy baryons.

Thank you for listening!!!

Back up

Axial-vector transition form factor for the singly heavy baryons compare with those of the light baryons



$\Delta S = 0$ **and** $\Delta Q = 0$ **Transition processes**

The axial-vector transition constants

- $\Delta S = 0$ and $\Delta Q = 0$ Transition processes

$g_A^{(3)}(0)$	$\Sigma_c^+ \to \Lambda_c^+$	$\Xi_c'^+ \to \Xi_c^+$	$\Xi_c'^0 \to \Xi_c^0$
$m_s = 0$ MeV	0.888	-0.461	0.462
$m_s = 180$ MeV	0.916	-0.468	0.469

$C_5^{A(3)}(0)$	$\Sigma_c^{*+} \to \Lambda_c^+$	$\Xi_c^{*+} \to \Xi_c^+$	$\Xi_c^{*0} \to \Xi_c^0$
$m_s = 0$ MeV	0.726	-0.381	0.382
$m_s = 180$ MeV	0.749	-0.388	0.388

- $\Delta S = 0$ and $\Delta Q = 1$ Transition processes

$g_A^{(1+i2)}(0)$	$\Sigma_c^0 \to \Lambda_c^+$	$\Xi_c'^0 \to \Xi_c^+$
$m_s = 0$ MeV	1.256	0.924
$m_s = 180$ MeV	1.294	0.938

$C_5^{A(1+i2)}(0)$	$\Sigma_c^{*0} \to \Lambda_c^+$	$\Xi_c^{*0} \to \Xi_c^+$
$m_s = 0$ MeV	1.028	0.765
$m_s = 180$ MeV	1.061	0.777

- $\Delta S = 0$ and $\Delta Q = -1$ Transition processes

$g_A^{(1-i2)}(0)$	$\Sigma_c^{++} \to \Lambda_c^+$	$\Xi_c'^+ \to \Xi_c^0$
$m_s = 0$ MeV	-1.256	0.922
$m_s = 180$ MeV	-1.294	0.936

$C_5^{A(1-i2)}(0)$	$\Sigma_c^{*0} \to \Lambda_c^+$	$\Xi_c^{*0} \to \Xi_c^+$
$m_s = 0$ MeV	-1.028	0.763
$m_s = 180$ MeV	-1.061	0.775

The axial-vector transition constants

- $\Delta S = 1$ **and** $\Delta Q = 1$ **Transition processes**

$g_A^{(4+i5)}(0)$	$\Xi_c^{\prime 0} \to \Lambda_c^+$	$\Omega_c^0 \to \Xi_c^+$
$m_s = 0$ MeV	1.347	0.952
$m_s = 180$ MeV	1.312	0.927

$C_5^{A(4+i5)}(0)$	$\Xi_c^{*0} \to \Lambda_c^+$	$\Omega_c^{*0} \to \Xi_c^+$
$m_s = 0$ MeV	1.159	0.820
$m_s = 180$ MeV	1.129	0.799

- $\Delta S = 1$ **and** $\Delta Q = 0$ **Transition processes**

$g_A^{(6+i7)}(0)$	$\Xi_c^{\prime +} \to \Lambda_c^+$	$\Omega_c^0 \to \Xi_c^0$
$m_s = 0$ MeV	-0.952	-1.347
$m_s = 180$ MeV	-0.927	-1.311

$C_5^{A(6+i7)}(0)$	$\Xi_c^{*+} \to \Lambda_c^+$	$\Omega_c^{*0} \to \Xi_c^0$
$m_s = 0$ MeV	-0.819	-1.160
$m_s = 180$ MeV	-0.798	-1.130

- $\Delta S = -1$ **and** $\Delta Q = -1$ **Transition processes**

$g_A^{(4-i5)}(0)$	$\Sigma_c^{++} \to \Xi_c^+$	$\Sigma_c^+ \to \Xi_c^0$
$m_s = 0$ MeV	0.786	-1.192
$m_s = 180$ MeV	0.808	-1.203

$C_5^{A(4-i5)}(0)$	$\Sigma_c^{*++} \to \Xi_c^+$	$\Sigma_c^{*+} \to \Xi_c^0$
$m_s = 0$ MeV	0.627	-0.956
$m_s = 180$ MeV	0.648	-0.969

- $\Delta S = -1$ **and** $\Delta Q = 0$ **Transition processes**

$g_A^{(6-i7)}(0)$	$\Sigma_c^+ \to \Xi_c^+$	$\Sigma_c^0 \to \Xi_c^0$
$m_s = 0$ MeV	0.787	1.196
$m_s = 180$ MeV	0.809	1.206

$C_5^{A(6-i7)}(0)$	$\Sigma_c^{*+} \to \Xi_c^+$	$\Sigma_c^{*0} \to \Xi_c^0$
$m_s = 0$ MeV	0.628	0.959
$m_s = 180$ MeV	0.649	0.972