Hyperon and charmed baryon productions with an instanton interaction

Sang-In Shim

RCNP, Osaka University

17 June 2019

Collaborated with Prof. Atsushi Hosaka and Prof. Hyun-Chul Kim

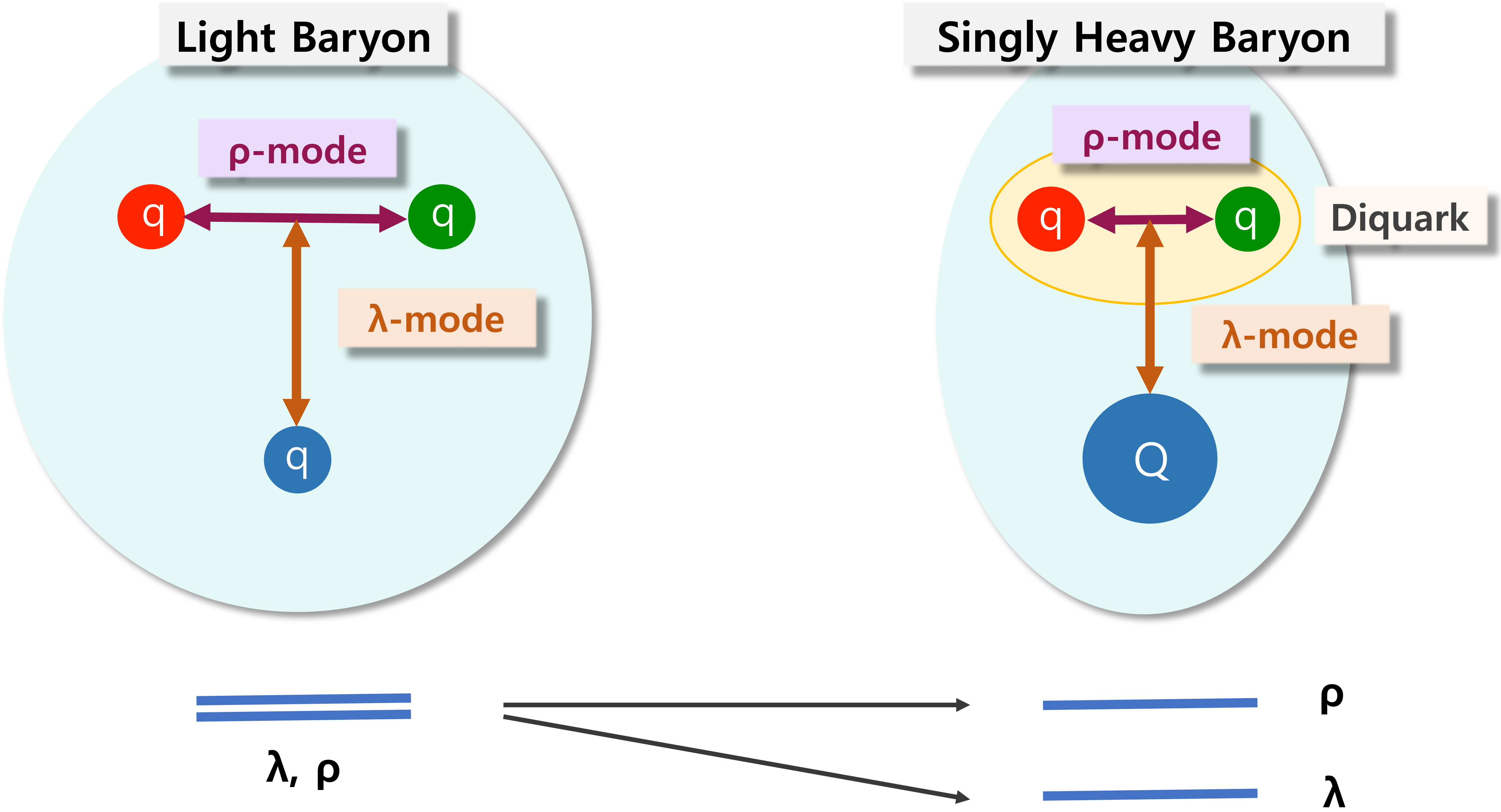
List of contents

- Background and Motivation
  - Heavy baryons and Diquarks
  - Researches on heavy baryon productions
- Methods for heavy baryon productions
  - One- and Two-quark processes
  - Baryon wave functions
  - Kinematics and Transition amplitudes
- Results and Discussion
- Summary and Outlook

List of contents

- Background and Motivation
  - Heavy baryons and Diquarks
  - Researches on heavy baryon productions
- Methods for heavy baryon productions
  - One- and Two-quark processes
  - Baryon wave functions
  - Kinematics and Transition amplitudes
- Results and Discussion
- Summary and Outlook

Heavy baryons and Diquarks



- Baryon excitations can be expressed as λ- and ρ-modes
- λ- and ρ-modes show distinct difference in heavy baryons

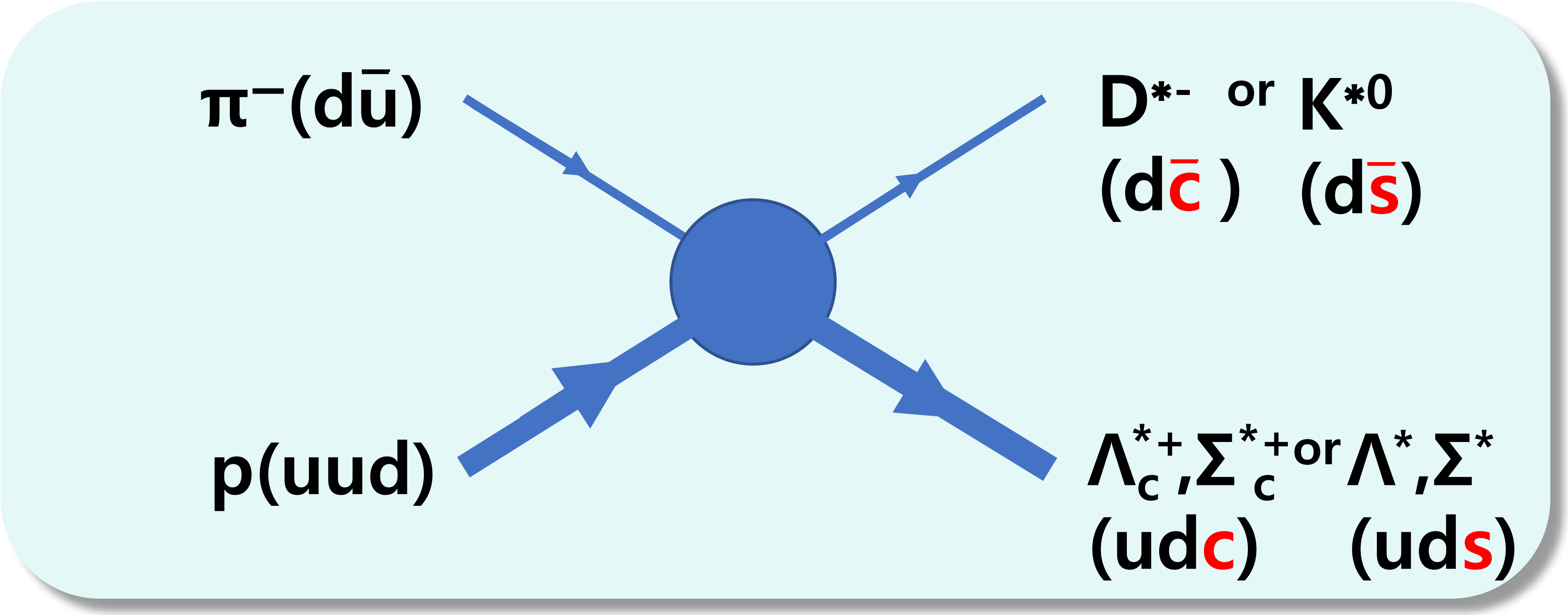
Researches on heavy baryon productions

Experiments[1,2]

- Early experiment at Brookhaven in 1985
- New experiment is planned at J-PARC by the high momentum pion beam

Former theoretical research[3,4]

- The production rates of heavy baryons were predicted
- Only λ-mode excitations were studied



[1] J.H.Christenson, E.Hummel, G.A.Kreiter, J.Sculli, PRL55, 154(1985)
[2] Charmed baryon spectroscopy via the (π, D^{*-}) reaction (2012). J-PARC P50 proposal.
[3] S.-H.Kim, A.Hosaka, H.-Ch.Kim, H.Noumi and K.Shirotori, PTEP(2014)no.10, 103D01.
[4] S.-H.Kim, A.Hosaka, H.-Ch.Kim, H.Noumi, PRD92(2014)no.9, 094021.

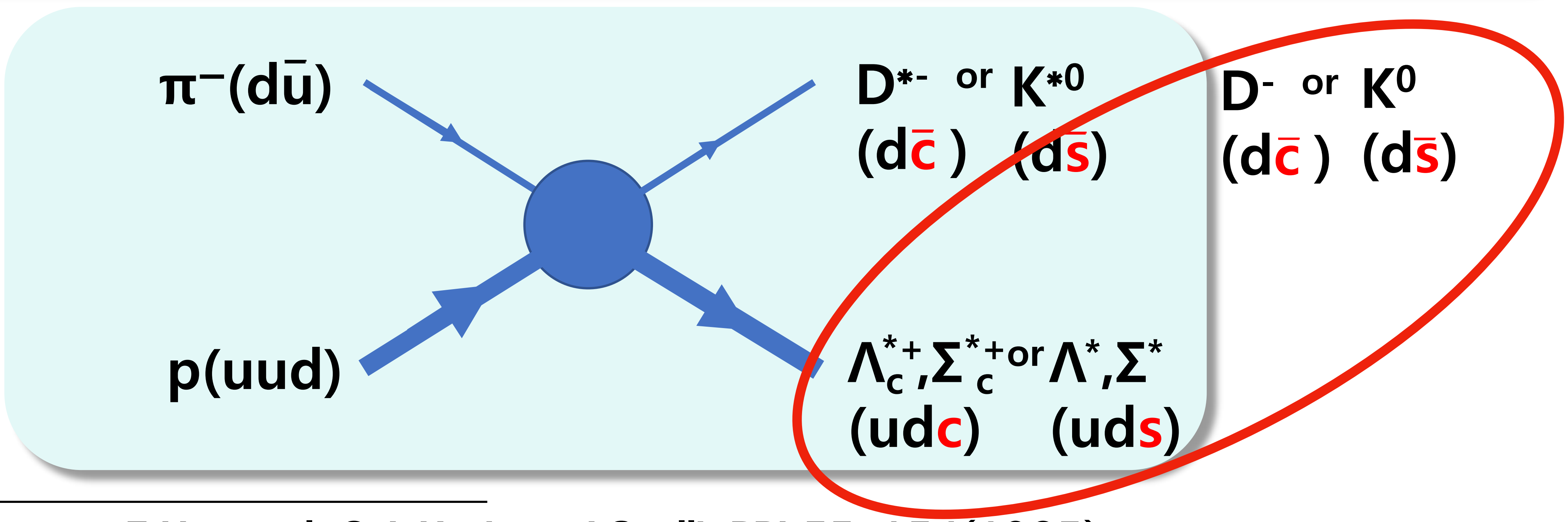
Researches on heavy baryon productions

Experiments[1,2]

- Early experiment at Brookhaven in 1985
- New experiment is planned at J-PARC by the high momentum pion beam

Former theoretical research[3,4]

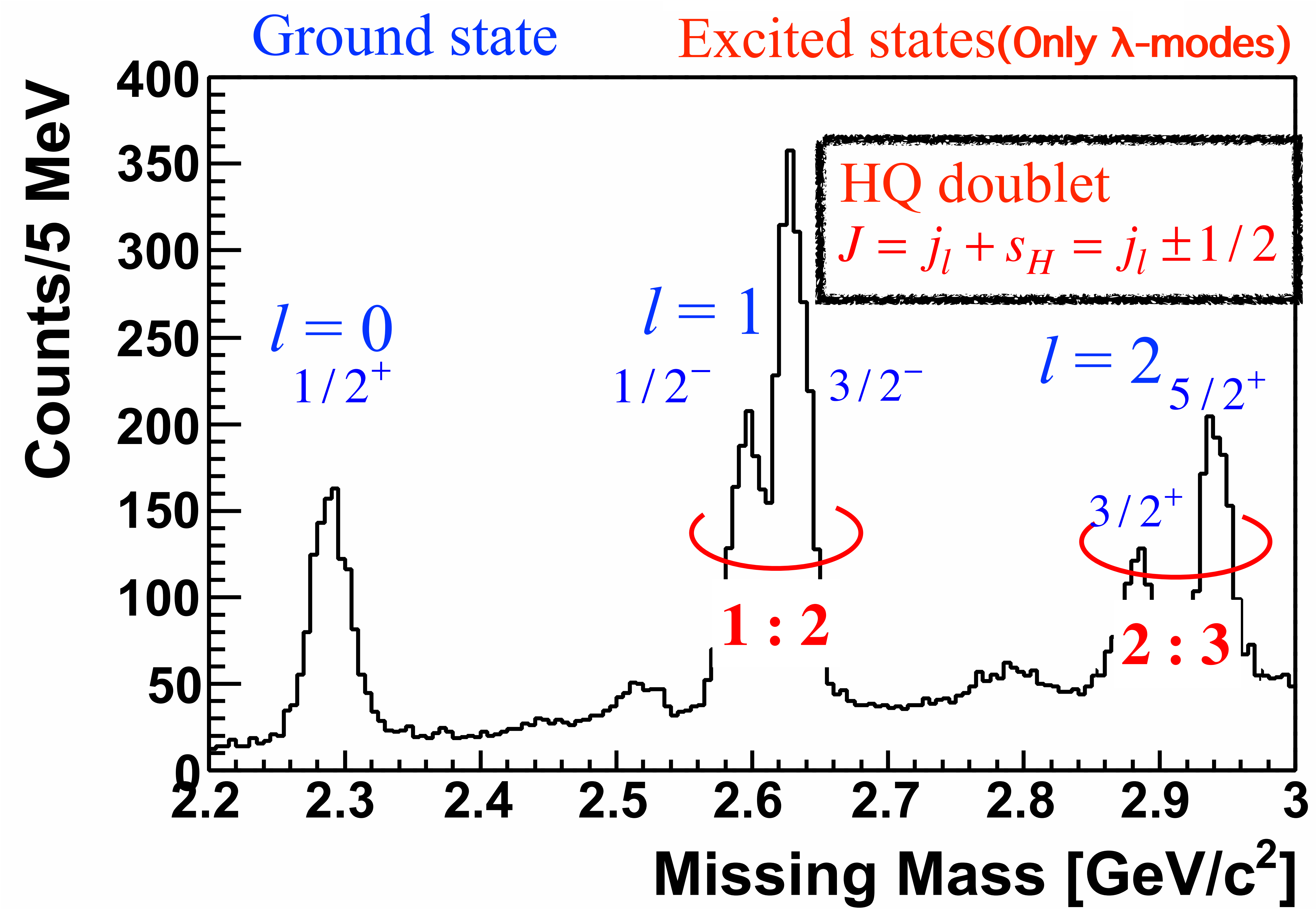
- The production rates of heavy baryons were predicted
- Only λ-mode excitations were studied



[1] J.H.Christenson, E.Hummel, G.A.Kreiter, J.Sculli, PRL55, 154(1985)
[2] Charmed baryon spectroscopy via the (π, D^{*-}) reaction (2012). J-PARC P50 proposal.
[3] S.-H.Kim, A.Hosaka, H.-Ch.Kim, H.Noumi and K.Shirotori, PTEP(2014)no.10, 103D01.
[4] S.-H.Kim, A.Hosaka, H.-Ch.Kim, H.Noumi, PRD92(2014)no.9, 094021.

Researches on heavy baryon productions

Charm production spectrum (Kim, Hosaka, Kim, Noumi, 2015)

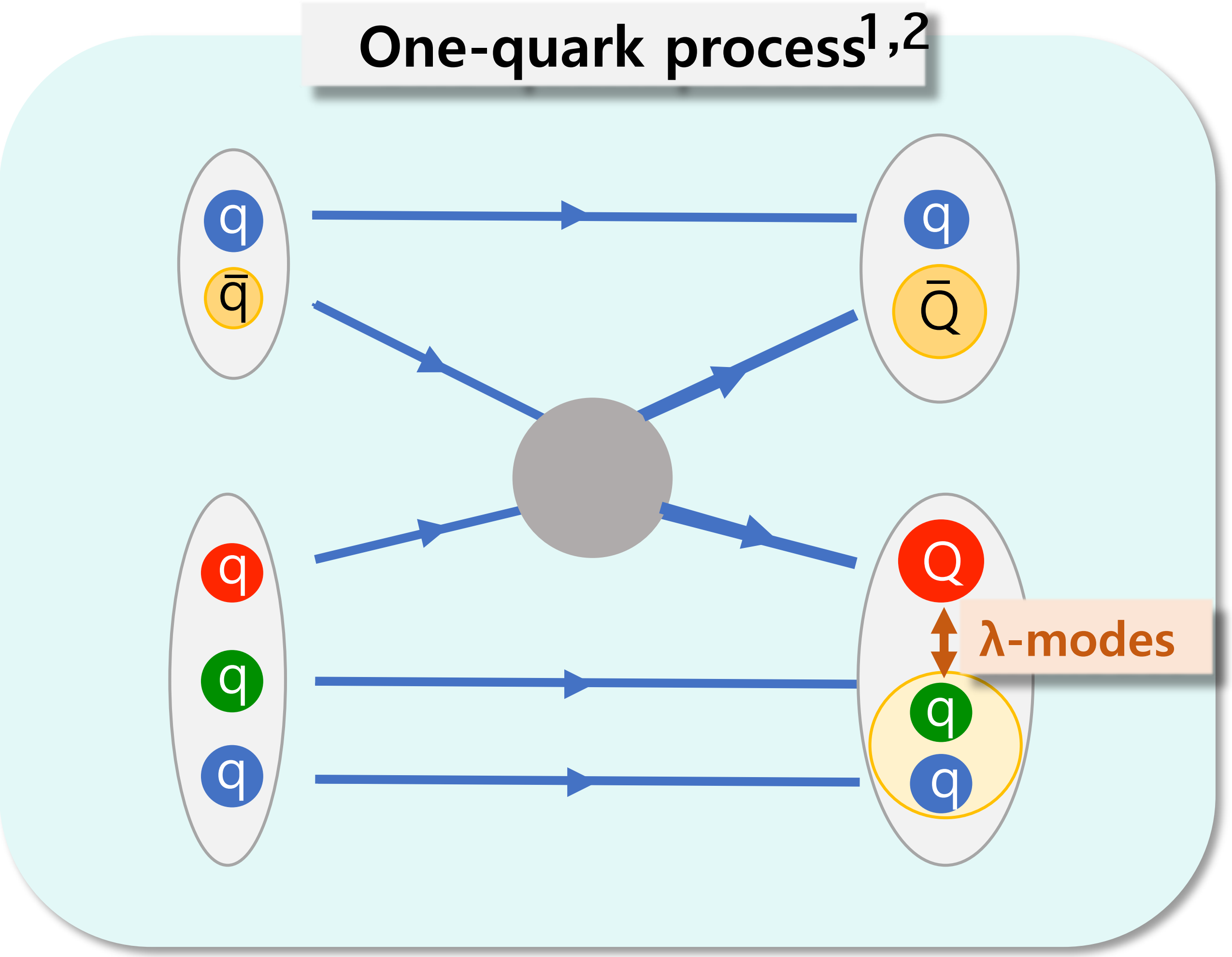


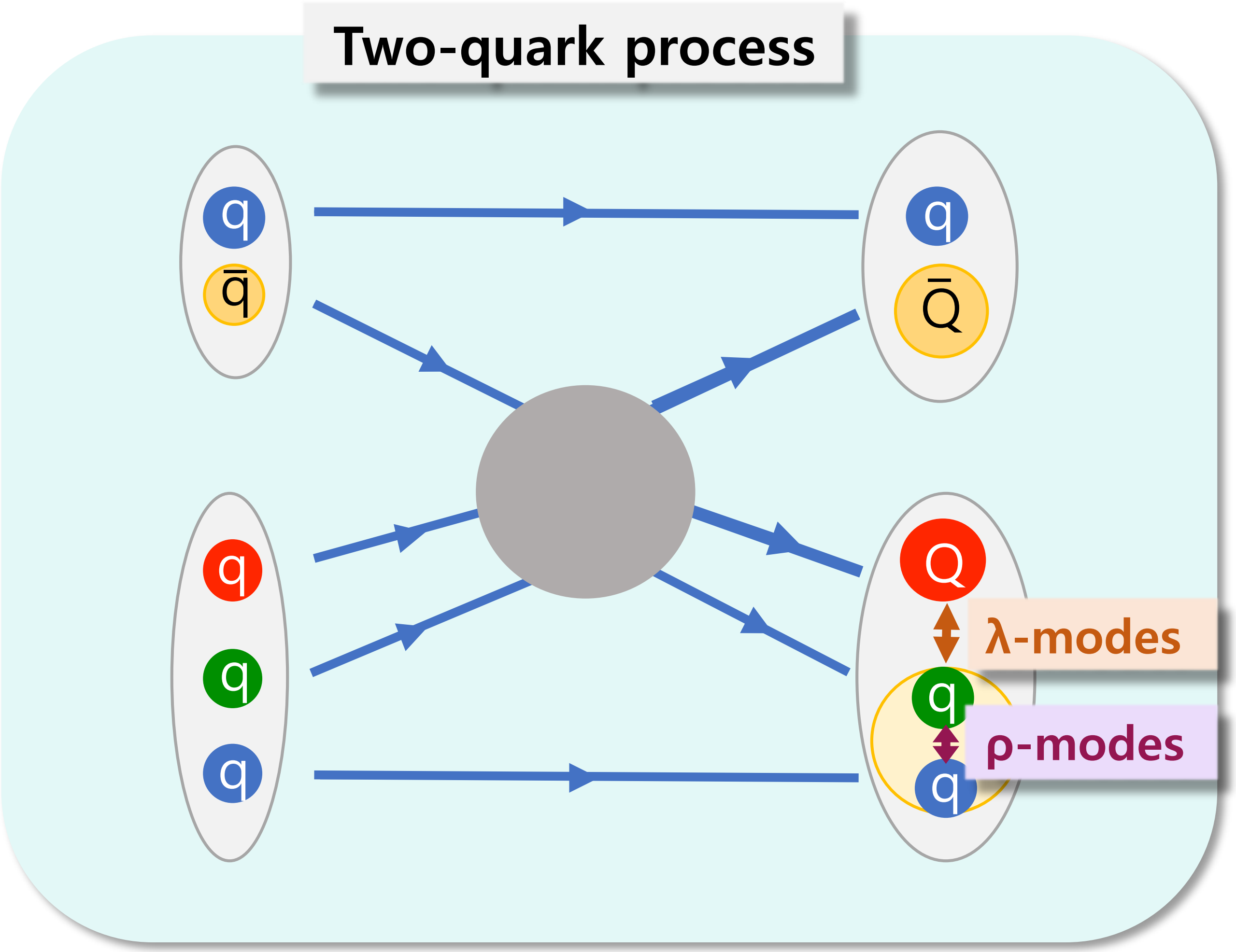
Motivation

- Propose a process to excite both λ- and ρ-modes
- Describe heavy baryon productions
  and find observables such as production rates
- Provide a careful discussion about structures and production rates of g.s, λ- and ρ-modes for various heavy baryons

List of contents

One- and two-quark processes



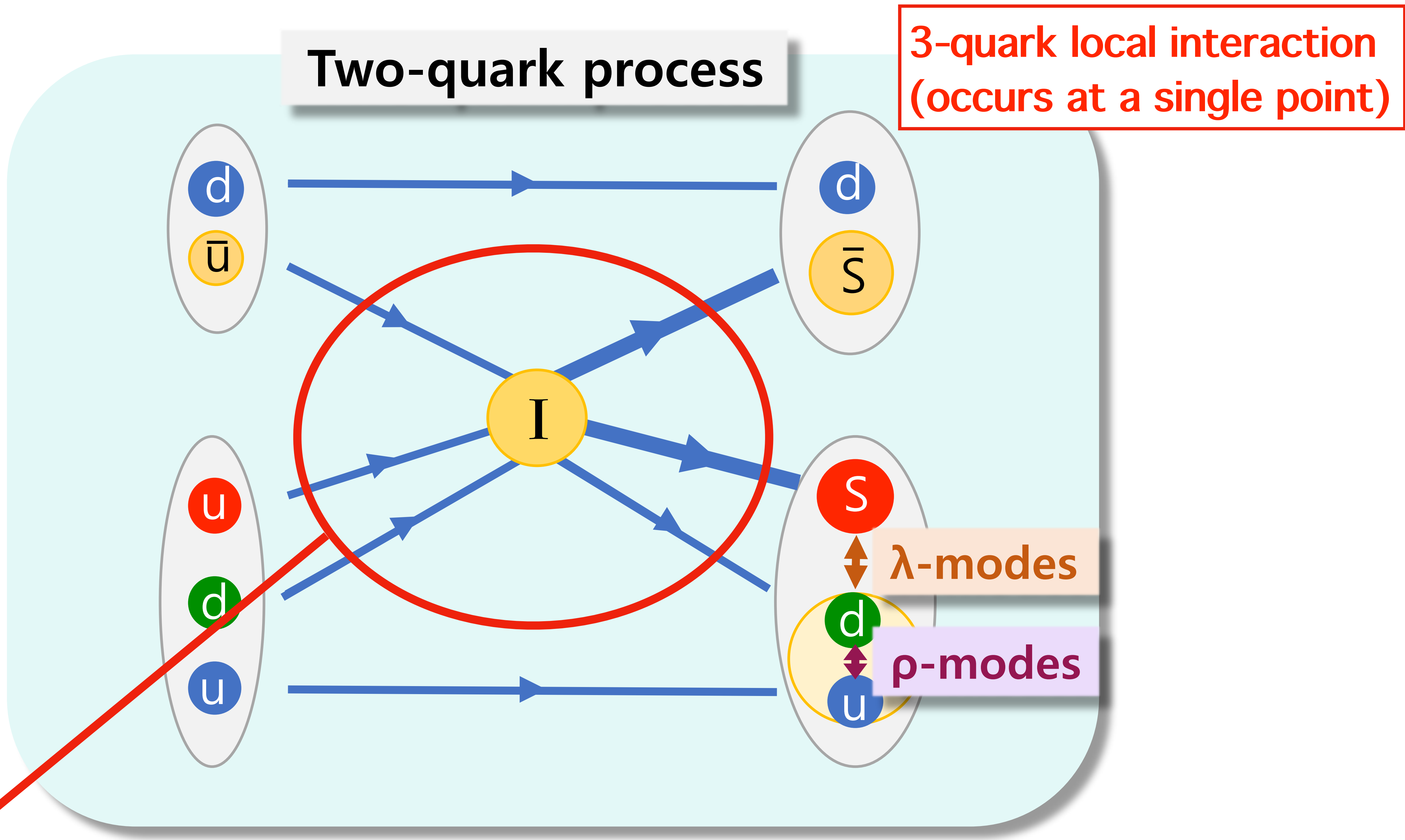


- One-quark process[1,2]
  - One quark in the baryon is involved in the interaction
  - The heavy baryon can be excited only to λ-modes
- Two-quark process
  - Both ρ- and λ-modes can be found
  - Need to consider 3-quark interactions or two-step precesses

---

[1] S.-H.Kim, A.Hosaka, H.-Ch.Kim, H.Noumi and K.Shirotori, PTEP(2014)no.10, 103D01.
[2] S.-H.Kim, A.Hosaka, H.-Ch.Kim, H.Noumi, PRD92(2014)no.9, 094021.

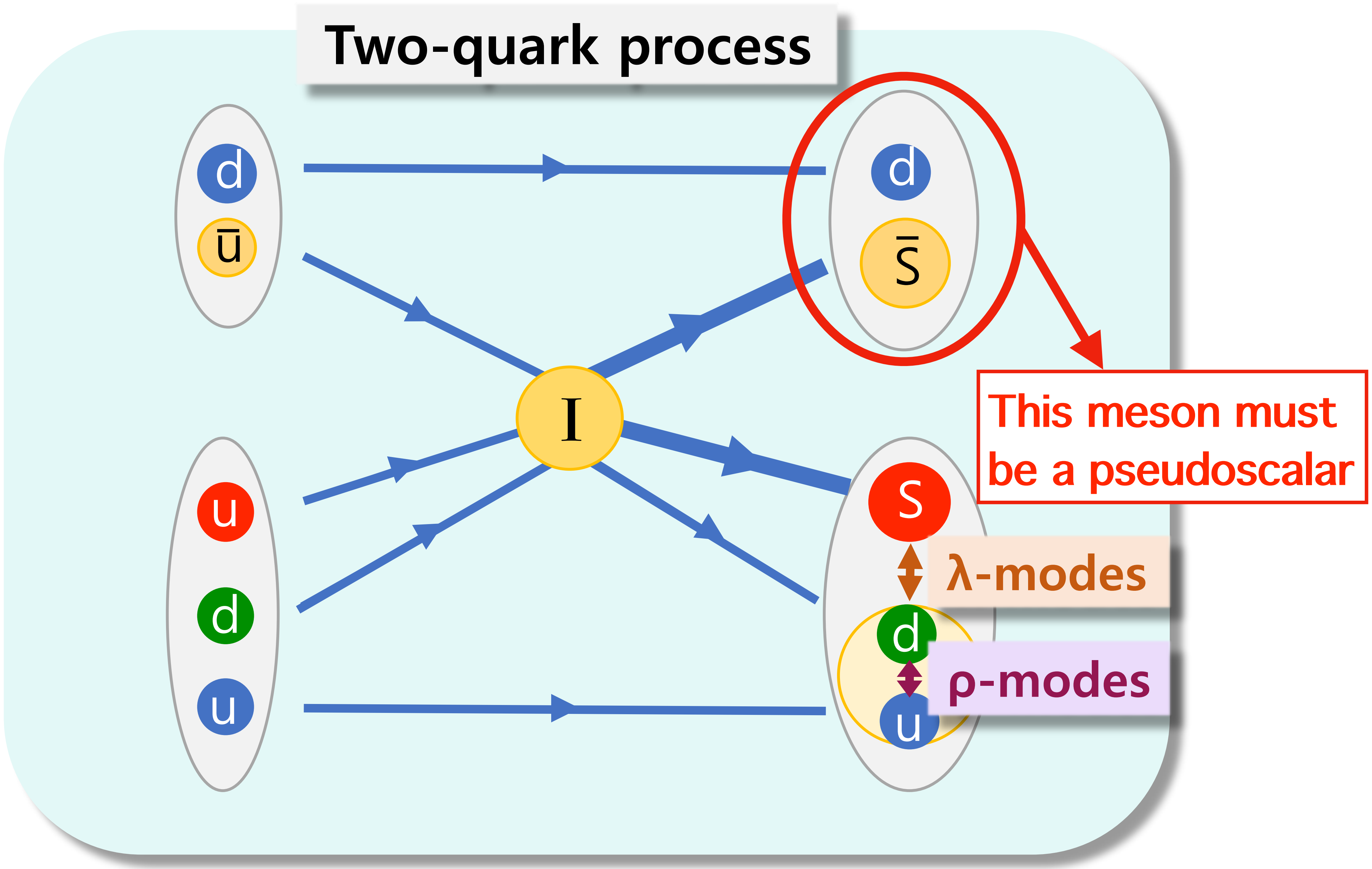
Quark interactions from the instanton model ('t Hooft interaction)



$$\mathcal{L}_{tH} = g\ \det(\bar{q}_i(1+\gamma_5)q_j) + H.c. = g \begin{vmatrix} \bar{u}(1+\gamma_5)u & \bar{u}(1+\gamma_5)d & \bar{u}(1+\gamma_5)s \\ \bar{d}(1+\gamma_5)u & \bar{d}(1+\gamma_5)d & \bar{d}(1+\gamma_5)s \\ \bar{s}(1+\gamma_5)u & \bar{s}(1+\gamma_5)d & \bar{s}(1+\gamma_5)s \end{vmatrix} + H.c.$$

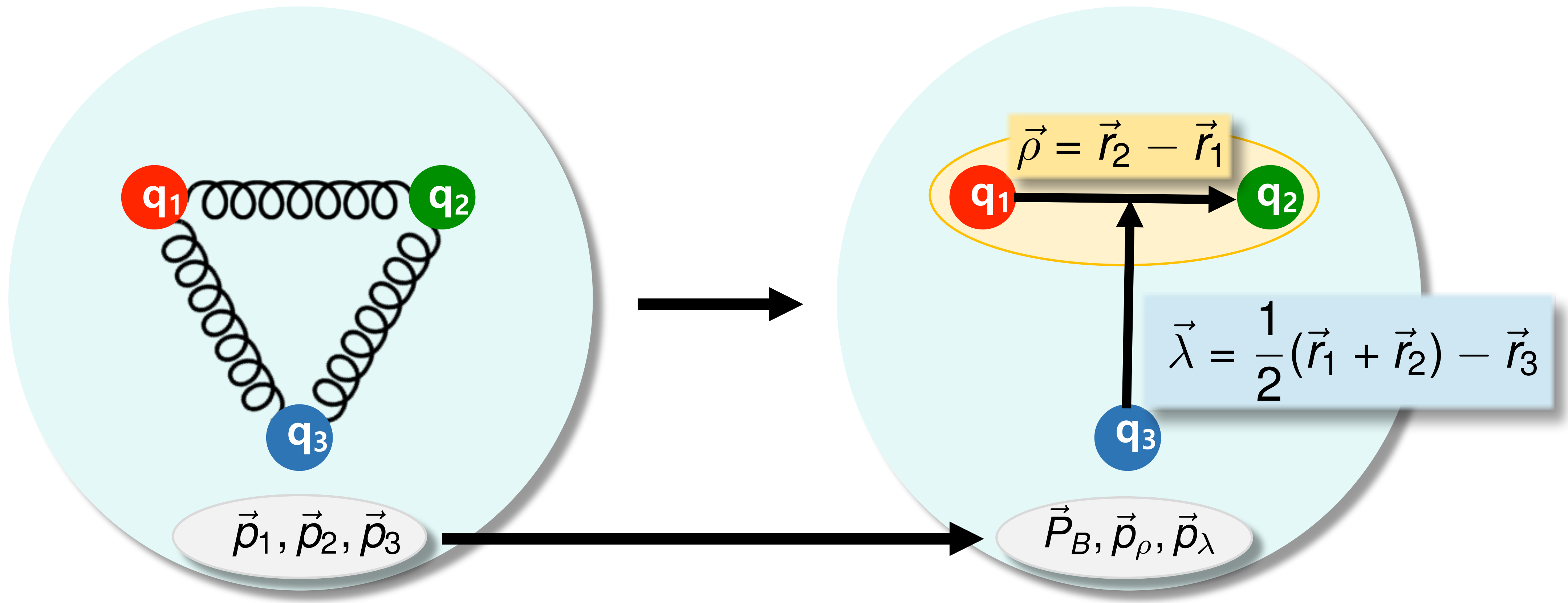
g is not determined yet
for charm quark sector

Quark interactions from the instanton model (’t Hooft interaction)



$$\mathcal{L}_{tH} = g\ \det(\bar{q}_i(1+\gamma_5)q_j) + H.c. = g \begin{vmatrix} \bar{u}(1+\gamma_5)u & \bar{u}(1+\gamma_5)d & \bar{u}(1+\gamma_5)s \\ \bar{d}(1+\gamma_5)u & \bar{d}(1+\gamma_5)d & \bar{d}(1+\gamma_5)s \\ \bar{s}(1+\gamma_5)u & \bar{s}(1+\gamma_5)d & \bar{s}(1+\gamma_5)s \end{vmatrix} + H.c.$$

Baryon wave functions ($m_1 = m_2 = m_q$)



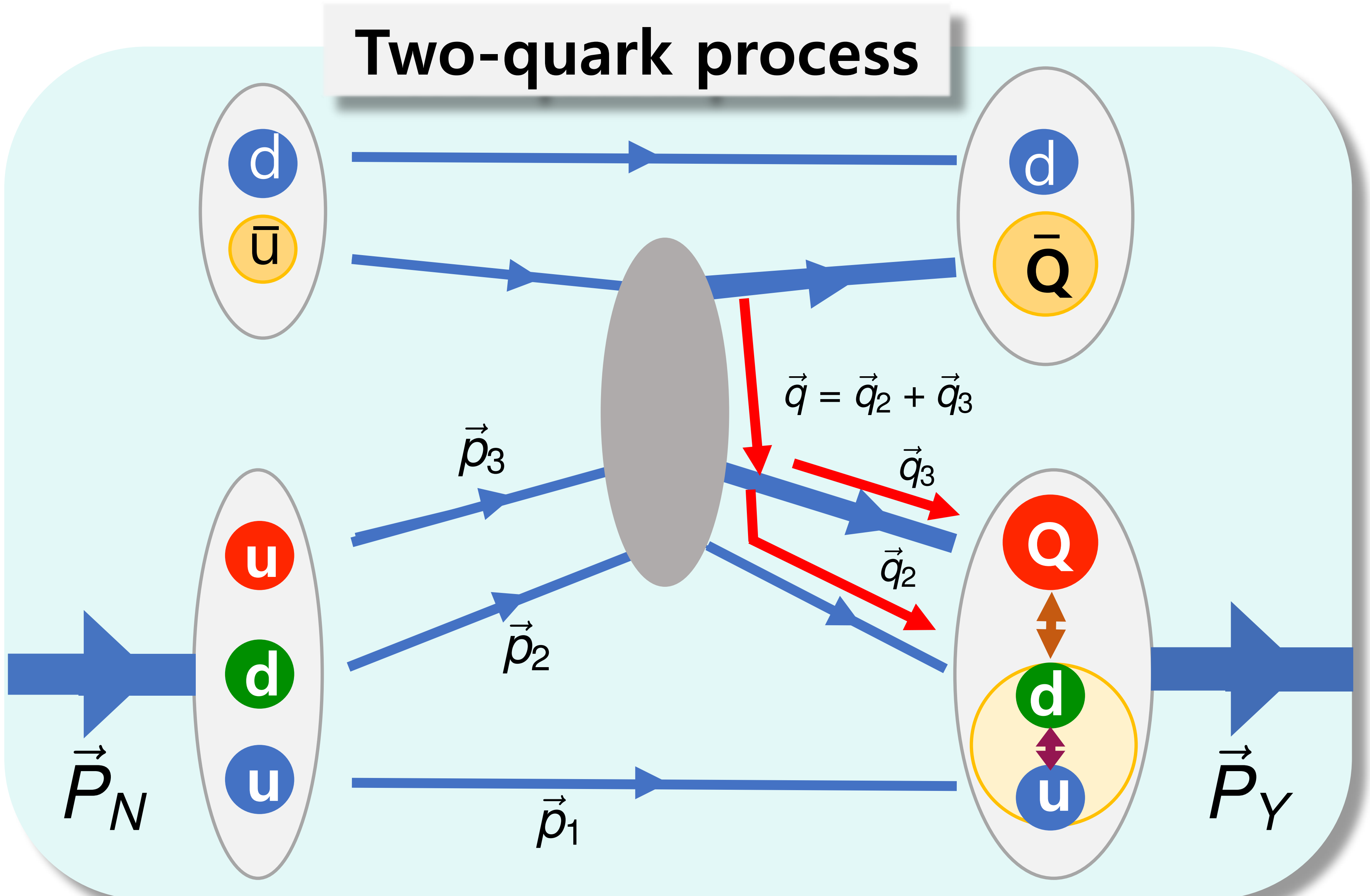
$$H = \sum_i \frac{\vec{p}_i^{\,2}}{2m_i} + \sum_{i<j} \frac{k}{2} |\vec{r}_i - \vec{r}_j|^2$$

$$= \frac{\vec{P}_B^2}{2M_B} + \boxed{\frac{\vec{p}_\rho^{\,2}}{2m_\rho} + \frac{\vec{p}_\lambda^{\,2}}{2m_\lambda} + \frac{1}{2} m_\rho \omega_\rho^2 \vec{\rho}^{\,2} + \frac{1}{2} m_\lambda \omega_\lambda^2 \vec{\lambda}^2}$$

3D Harmonic oscillators of $\vec{\rho}$ and $\vec{\lambda}$

$$\vec{p}_\rho = \frac{1}{2}(\vec{p}_2 - \vec{p}_1), \quad \vec{p}_\lambda = \frac{m_3}{2m_q + m_3}(\vec{p}_1 + \vec{p}_2) - \frac{2m_q}{2m_q + m_3}\vec{p}_3$$

Kinematics for heavy baryon productions



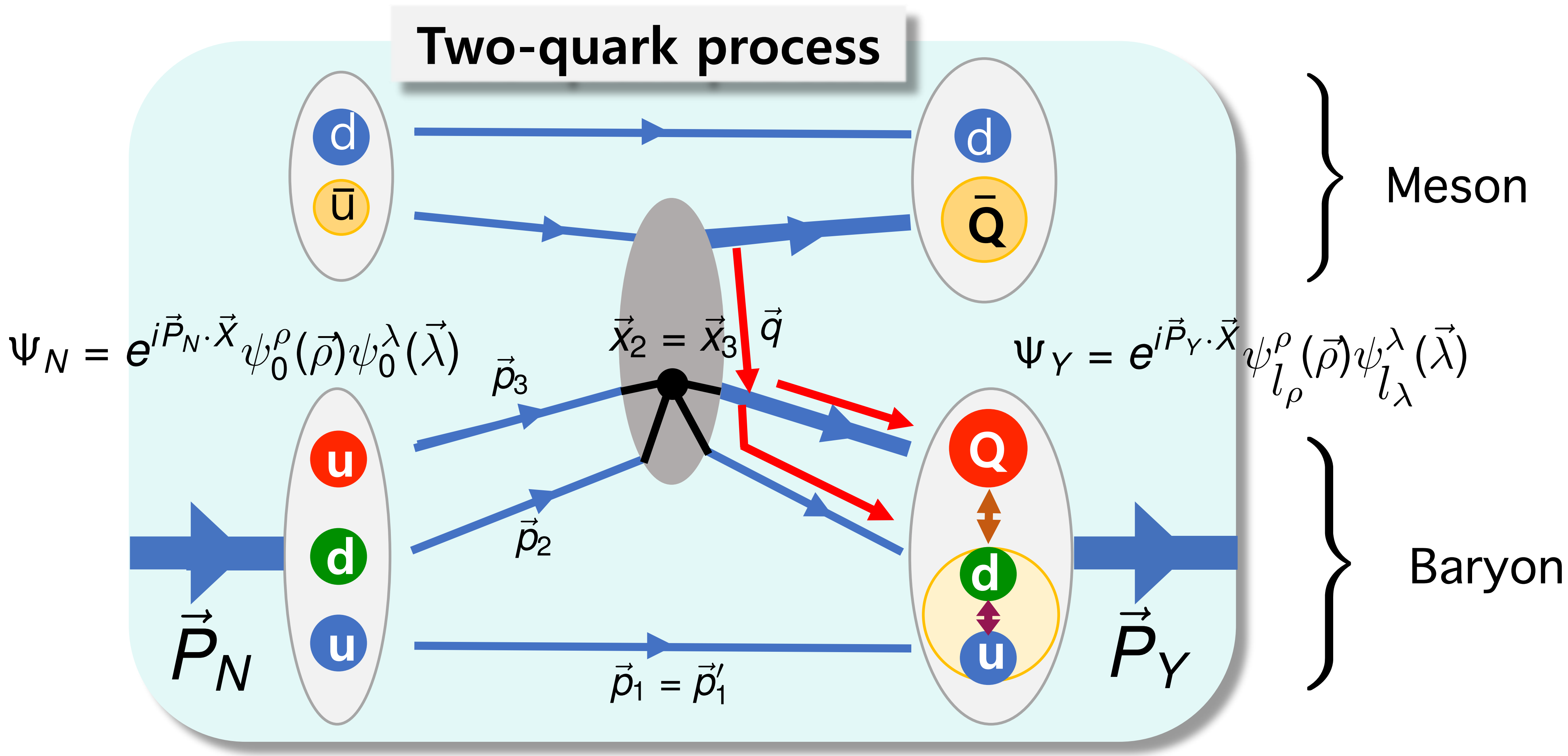
$$\vec{P}_N = \sum_i \vec{p}_i \longrightarrow \vec{P}_Y = \sum_i \vec{p'}_i = \vec{P}_N + \vec{q}$$

$$(\vec{p}_\rho, \ \vec{p}_\lambda) \longrightarrow (\vec{p}_\rho + \vec{q}_\rho, \ \vec{p}_\lambda + \vec{q}_\lambda)$$

$$\vec{q}_\rho = \frac{1}{2}\vec{q}_2,$$

$$\vec{q}_\lambda = \vec{q}_2 + \vec{q}_{eff} = \vec{q}_2 + \left(\frac{2}{3}\vec{P}_N - \frac{2m_q}{2m_q + m_Q}\vec{P}_{Y(Y_c)} \right)$$

Matrix elements for two-quark processes



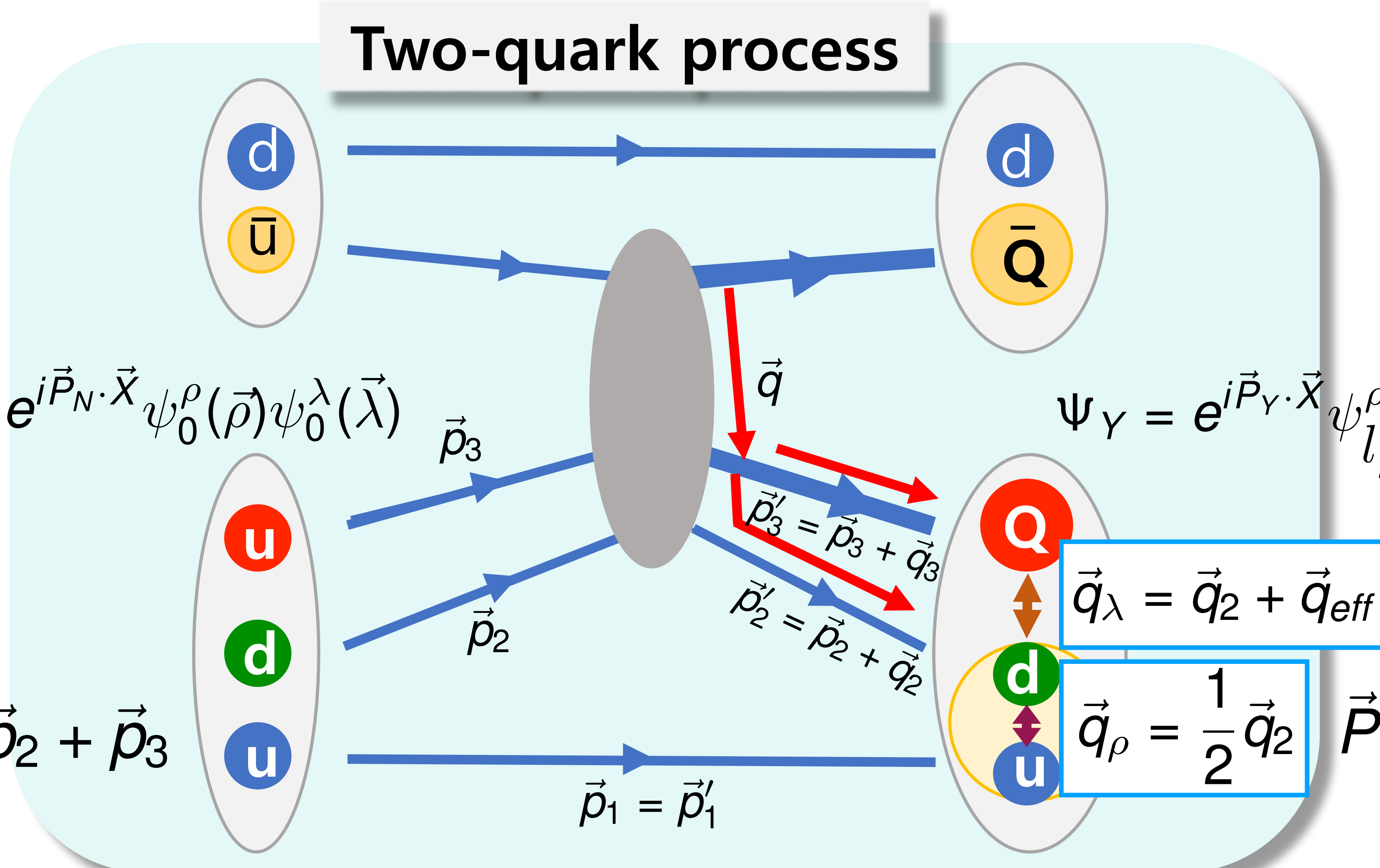
$$\langle \mathbf{Y}, M|\mathcal{L}_{tH}|p, \pi\rangle = \langle(Meson)\rangle \times \langle(Baryon)\rangle$$

$$\langle(Baryon)\rangle \sim C_Y\int d^3x_1\, d^3x_2\, d^3x_3\, \Psi_Y^*(\vec{x}_1,\vec{x}_2,\vec{x}_3)\underline{e^{i\vec{q}\cdot\vec{x}_3}\delta^3(\vec{x}_2-\vec{x}_3)}\Psi_N(\vec{x}_1,\vec{x}_2,\vec{x}_3)$$

Operator from $\mathcal{L}_{th}$

- $\vec{q}_{eff}$: Effective momentum transfer, $\vec{q}_{eff} = \frac{2}{3}\vec{p}_p - \frac{2m_q}{2m_q+m_Q}\vec{p}_{Y(Y_c)}$
- $\mathcal{L}_{tH}$: Interaction Lagrangian for the 3-quark interaction
- $\psi_l^{\rho \text{ or } \lambda(*)}$: Wave function for ρ- or λ- modes of the initial(final) state baryon

Matrix elements for two-quark processes



$$\Psi_N = e^{i\vec{P}_N\cdot\vec{X}}\psi_0^\rho(\vec{\rho})\psi_0^\lambda(\vec{\lambda}) \qquad \Psi_Y = e^{i\vec{P}_Y\cdot\vec{X}}\psi_{l_\rho}^\rho(\vec{\rho})\psi_{l_\lambda}^\lambda(\vec{\lambda})$$

$\vec{q}$, $\vec{p}_3$, $\vec{p}_2$, $\vec{p}_1 = \vec{p}'_1$, $\vec{p}'_3 = \vec{p}_3 + \vec{q}_3$, $\vec{p}'_2 = \vec{p}_2 + \vec{q}_2$

$$\vec{q}_\lambda = \vec{q}_2 + \vec{q}_{eff} \qquad \vec{q}_\rho = \frac{1}{2}\vec{q}_2$$

$$\vec{P}_N = \vec{p}_1 + \vec{p}_2 + \vec{p}_3 \qquad \vec{P}_Y = \vec{p'}_1 + \vec{p'}_2 + \vec{p'}_3$$

$$\langle \mathbf{Y}, M|\mathcal{L}_{tH}|p,\pi\rangle \sim C_{YM}\,\delta^{(3)}\left(\vec{p}_Y - \vec{p}_p - \vec{q}\right)\int d^3q_2\, d^3q_3\,\delta^{(3)}\left(\vec{q} - \vec{q}_2 - \vec{q}_3\right)$$
$$\times \int d^3\rho\, e^{i\vec{q}_\rho\cdot\vec{\rho}}\psi_{l_\rho}^{\rho *}(\vec{\rho})\psi_0^\rho(\vec{\rho})\int d^3\lambda\, e^{i\vec{q}_\lambda\cdot\vec{\lambda}}\psi_{l_\lambda}^{\lambda' *}(\vec{\lambda})\psi_0^\lambda(\vec{\lambda})$$

- $\vec{q}_{eff}$: Effective momentum transfer, $\vec{q}_{eff} = \frac{2}{3}\vec{p}_p - \frac{2m_q}{2m_q+m_Q}\vec{p}_{Y(Y_c)}$
- $\mathcal{L}_{tH}$: Interaction Lagrangian for the 3-quark interaction
- $\psi_l^{\rho \text{ or } \lambda(*)}$: Wave function for ρ- or λ- modes of the initial(final) state baryon

List of contents

Comparison between One- and Two-quark processes

- One-quark processes[1] (former work)

$$\langle Y(\tfrac{1}{2}^+,\ l=0), M|\mathcal{L}_{int}|p,\pi^-\rangle \propto exp\left[-\frac{q_{eff}^2}{4A^2}\right]$$

$$\langle Y(\tfrac{1}{2}^-,\ l_\lambda=1), M|\mathcal{L}_{int}|p,\pi^-\rangle \propto \frac{\alpha_{\lambda'}|\vec{q}_{eff}|}{\sqrt{2}A^2} exp\left[-\frac{q_{eff}^2}{4A^2}\right]$$

- Two-quark processes(present work)

$$\langle Y(\tfrac{1}{2}^+,\ l=0), M|\mathcal{L}_{tH}|p,\pi^-\rangle \propto exp\left[-\frac{q_{eff}^2}{4B^2}\right]$$

$$\langle Y(\tfrac{1}{2}^-,\ l_\lambda=1), M|\mathcal{L}_{tH}|p,\pi^-\rangle \propto \frac{\alpha_{\lambda'}|\vec{q}_{eff}|}{\sqrt{2}B^2} exp\left[-\frac{q_{eff}^2}{4B^2}\right]$$

$$\langle Y(\tfrac{1}{2}^-,\ l_\rho=1), M|\mathcal{L}_{tH}|p,\pi^-\rangle \propto \frac{\sqrt{2}\alpha_\rho|\vec{q}_{eff}|}{B^2} exp\left[-\frac{q_{eff}^2}{4B^2}\right]$$

$$A^2 = \frac{\alpha_{\lambda'}^2+\alpha_\lambda^2}{2}$$

$$B^2 = \frac{8\alpha_\rho^2+\alpha_{\lambda'}^2+\alpha_\lambda^2}{2}$$

$$\alpha_\xi = \sqrt{m_\xi\omega_\xi} \quad (\xi = \rho,\ \lambda,\ \lambda')$$

$$\omega_\rho^2 = \frac{3k}{2m_\rho},\ \omega_{\lambda(\lambda')}^2 = \frac{2k}{m_{\lambda(\lambda')}}$$

$$m_\rho = \frac{m_q}{2},\ m_\lambda = \frac{2}{3}m_q,\ m_{\lambda'} = \frac{2m_qm_Q}{2m_q+m_Q}$$

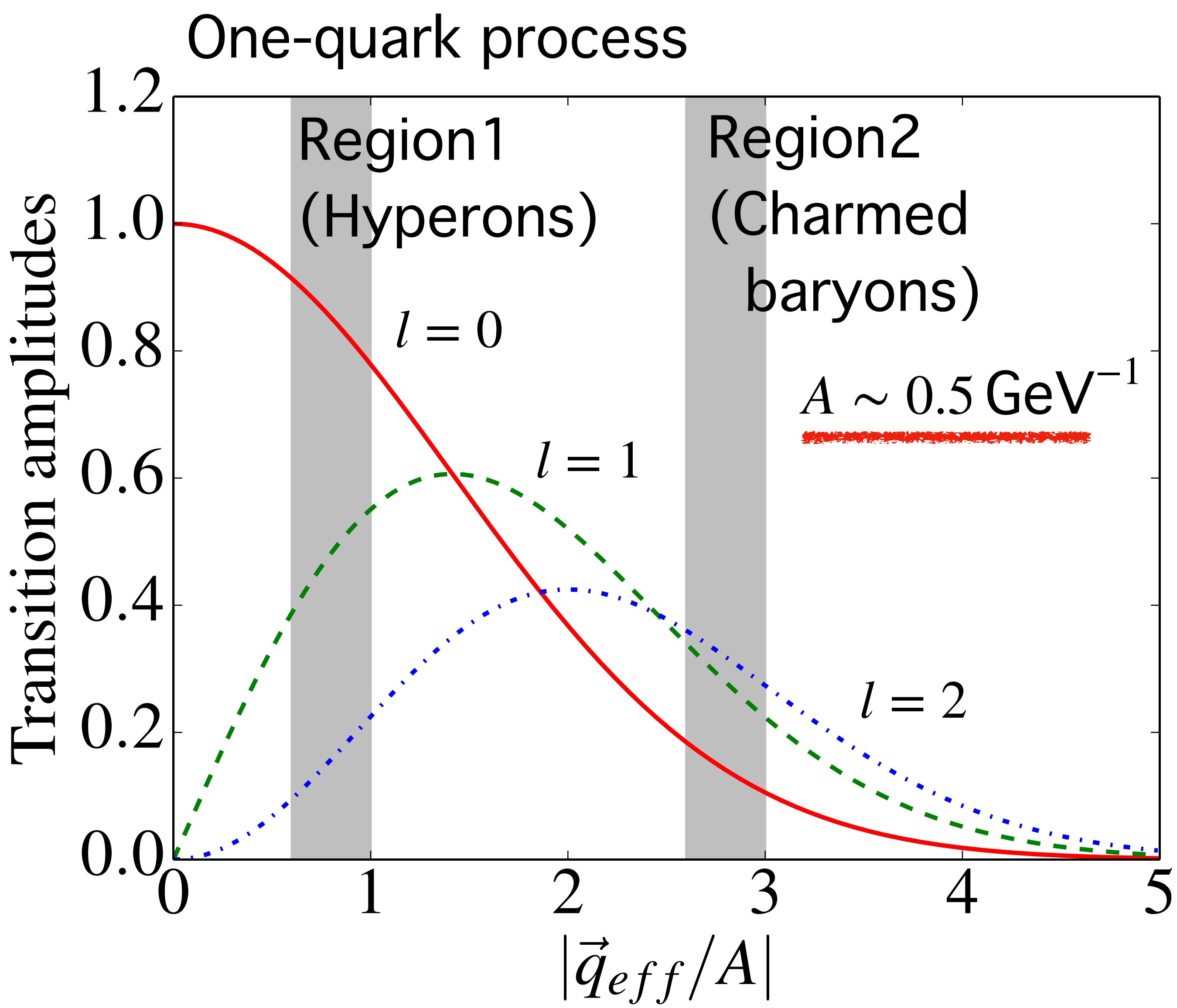
—>As $|\vec{q}_{eff}|$ increases, productions of

(1) Ground states decrease exponentially

(2) Excited states increase, reach a pick and decrease

[1] S.-H.Kim, A.Hosaka, H.-Ch.Kim, H.Noumi and K.Shirotori, PTEP(2014)no.10, 103D01.

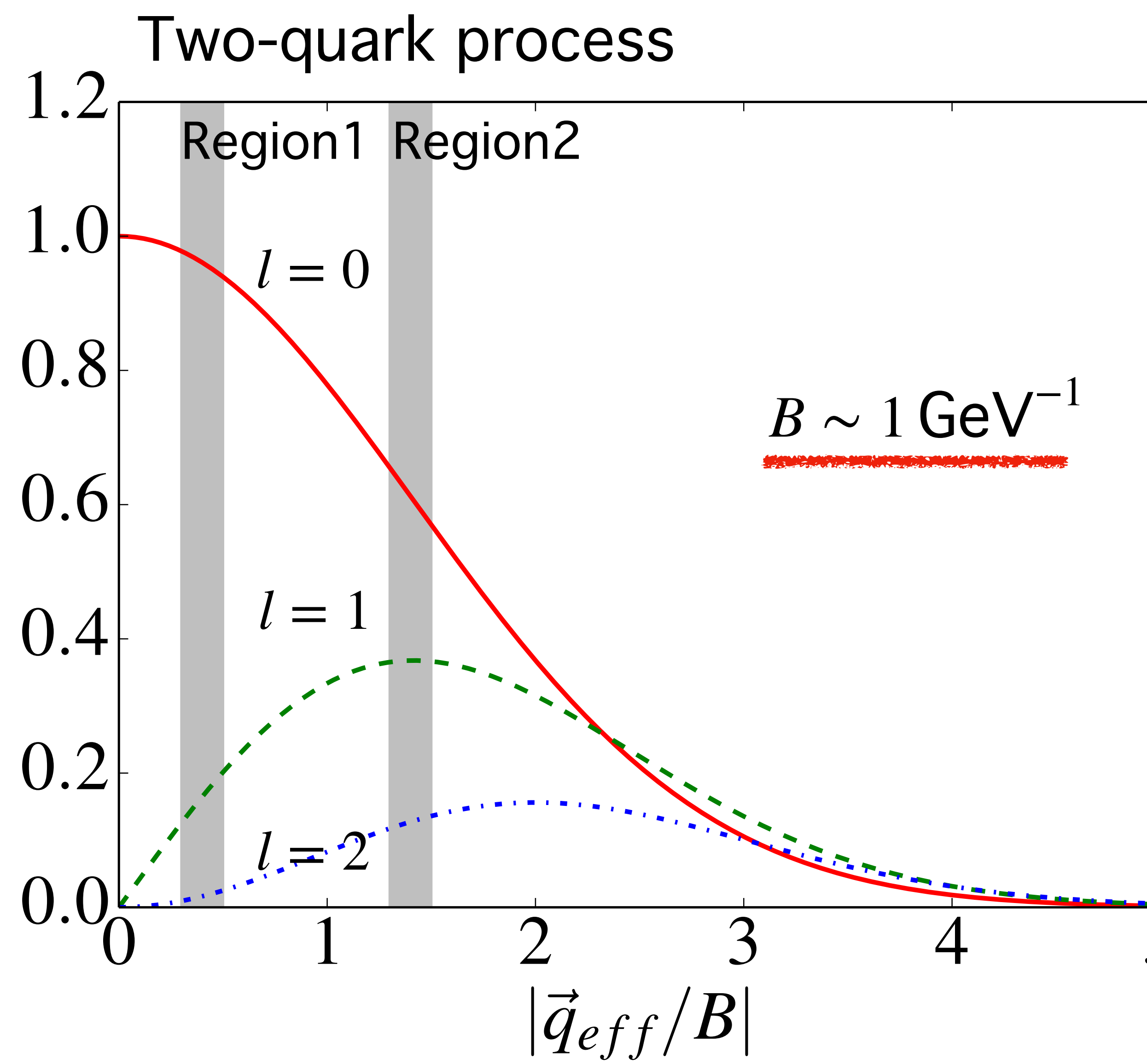
Comparison between One- and Two-quark processes(λ-mode)



$l = 0 : e^{-q_{eff}^2/(4A^2)}$

$l = 1 : \frac{1}{\sqrt{2}} \left| \frac{\alpha_{\lambda'} \vec{q}_{eff}}{A^2} \right| e^{-q_{eff}^2/(4A^2)}$

$l = 2 : \frac{1}{2\sqrt{3}} \left| \frac{\alpha_{\lambda'} \vec{q}_{eff}}{A^2} \right|^2 e^{-q_{eff}^2/(4A^2)}$

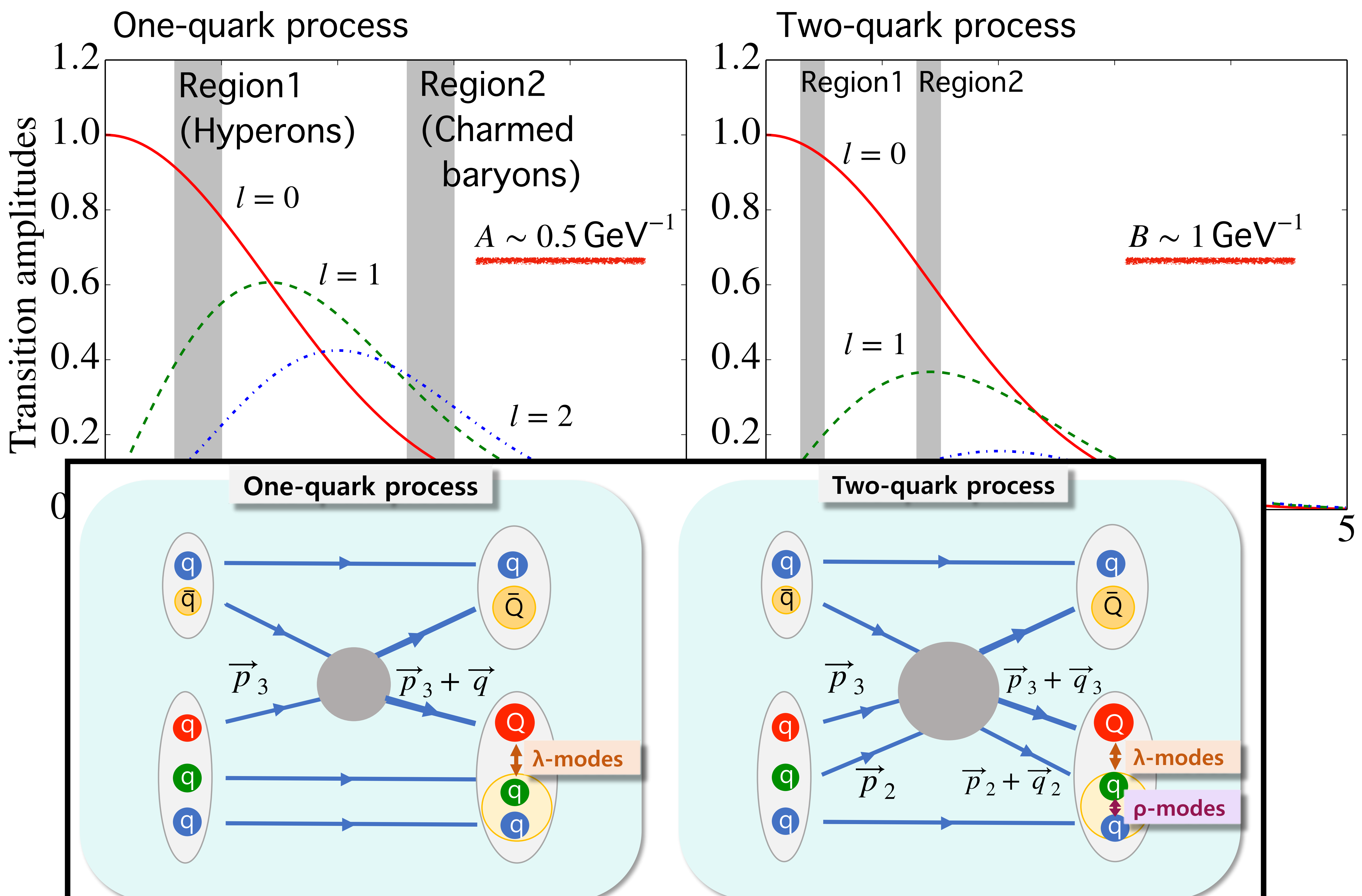


$l = 0 : e^{-q_{eff}^2/(4B^2)}$

$l = 1 : \frac{1}{\sqrt{2}} \left| \frac{\alpha_{\lambda'} \vec{q}_{eff}}{B^2} \right| e^{-q_{eff}^2/(4B^2)}$

$l = 2 : \frac{1}{2\sqrt{3}} \left| \frac{\alpha_{\lambda'} \vec{q}_{eff}}{B^2} \right|^2 e^{-q_{eff}^2/(4B^2)}$

Comparison between One- and Two-quark processes(λ-mode)



Production rates of the two-quark process(Preliminary)

π-p —>K^0Ys or D^-Yc
(forward scattering)

$$|\vec{k}_\pi^{Lab}| = \begin{cases} 5 & \text{GeV for Strange} \\ 20 & \text{GeV for Charmed} \end{cases}$$

G.S.	Λ(1/2+)	Σ(1/2+)	Σ(3/2+)
Rate(Ys)	1	3.3	0
Rate(Yc)	1	2.9	0

λ-modes	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Σ(1/2-,j=0)	Σ(1/2-,j=1)	Σ(3/2-,j=1)	Σ(3/2-,j=2)	Σ(5/2-,j=2)
Rate(Ys)	0.004	0.010	0.007	0.015	0.007	0.038	0
Rate(Yc)	0.10	0.20	0.12	0.23	0.12	0.58	0

ρ-modes	Λ(1/2-,j=0)	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Λ(3/2-,j=2)	Λ(5/2-,j=2)	Σ(1/2-,j=1)	Σ(3/2-,j=1)
Rate(Ys)	0.017	0.039	0.018	0.10	0	0.016	0.032
Rate(Yc)	0.22	0.43	0.22	1.1	0	0.20	0.41

[1] PDG2016, Chinese Physics C, 40, 100001

[2] T. Yoshida, E. Hiyama, A. Hosaka, M. Oka, and K. Sadato, PhysRevD.92.114029(2015)

Production rates of the two-quark process(Preliminary)

All production rates are normalized by $\Lambda_s(1/2+)$ or $\Lambda_c(1/2+)$

(forward scattering)

$$|\vec{k}_\pi^{Lab}| = \begin{cases} 5 & \text{GeV for Strange} \\ 20 & \text{GeV for Charmed} \end{cases}$$

G.S.	Λ(1/2+)	Σ(1/2+)	Σ(3/2+)
Rate(Ys)	1	3.3	0
Rate(Yc)	1	2.9	0

λ-modes	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Σ(1/2-,j=0)	Σ(1/2-,j=1)	Σ(3/2-,j=1)	Σ(3/2-,j=2)	Σ(5/2-,j=2)
Rate(Ys)	0.004	0.010	0.007	0.015	0.007	0.038	0
Rate(Yc)	0.10	0.20	0.12	0.23	0.12	0.58	0

ρ-modes	Λ(1/2-,j=0)	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Λ(3/2-,j=2)	Λ(5/2-,j=2)	Σ(1/2-,j=1)	Σ(3/2-,j=1)
Rate(Ys)	0.017	0.039	0.018	0.10	0	0.016	0.032
Rate(Yc)	0.22	0.43	0.22	1.1	0	0.20	0.41

---

[1]PDG2016, Chinese Physics C, 40, 100001

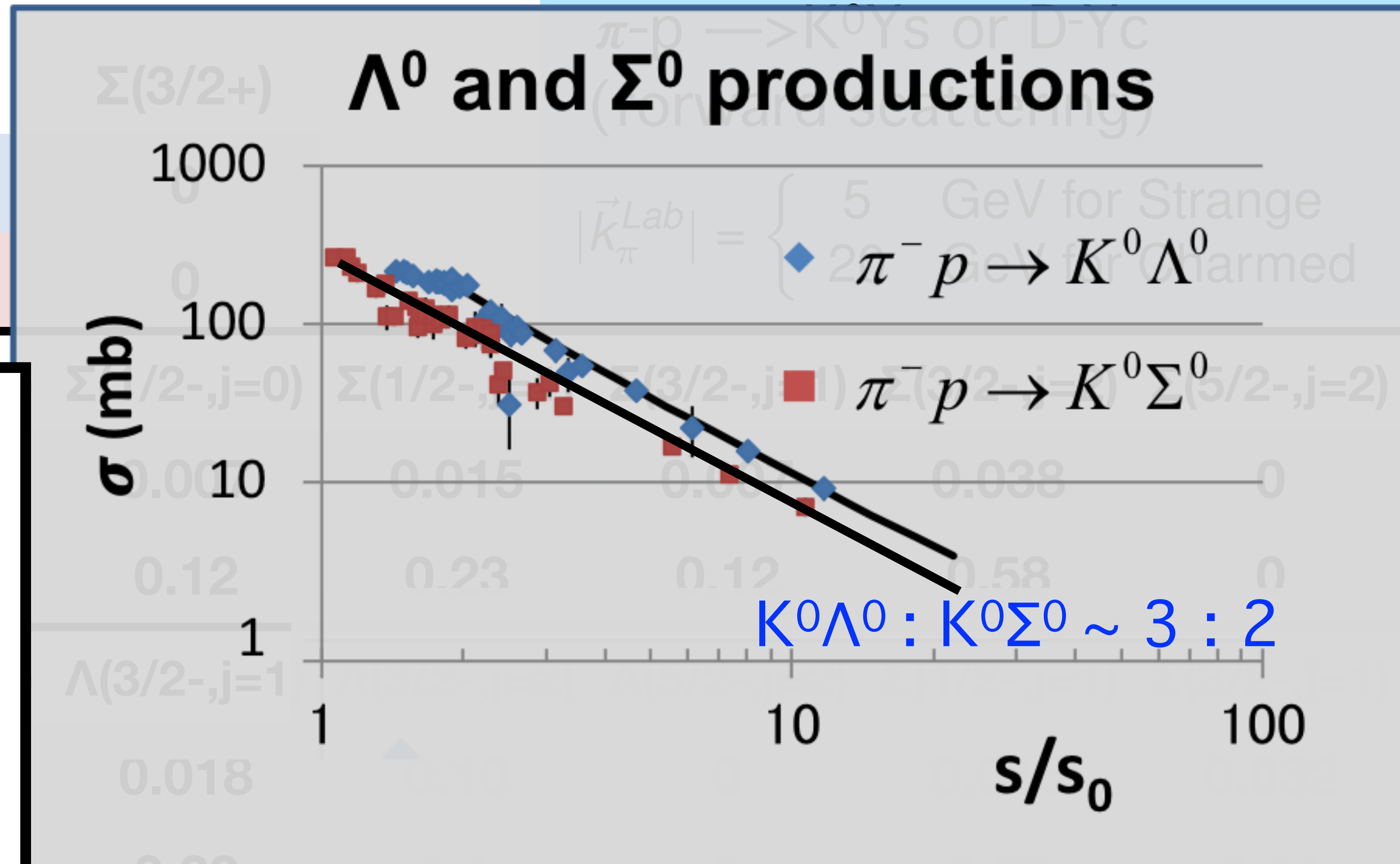
[2]T. Yoshida, E. Hiyama, A. Hosaka, M. Oka, and K. Sadato, PhysRevD.92.114029(2015)

Production rates of the two-quark process(Preliminary)

G.S.	Λ(1/2+)	Σ(1/2+)
Rate(Ys)	1	3.3
Rate(Yc)	1	2.9

Production rates of One-quark process for G.S. from π-p —>K*Ys

$l=0$	$\Lambda\left(\frac{1}{2}^+\right)$	$\Sigma\left(\frac{1}{2}^+\right)$
$\mathcal{R}(B_s)$	1	0.04



- Neither one- nor two-quark process alone can explain experimental data

Production rates of the two-quark process(Preliminary)

π-p —>K^{0}Ys or D$^-$Yc
(forward scattering)

$|\vec{k}_{Lab}|$ ∼ 5 GeV for Strange

G.S.	Λ(1/2+)	Σ(1/2+)	Σ(3/2+)
Rate(Ys)	**1**	**3.3**	**0**
Rate(Yc)	**1**	**2.9**	**0**

1 : 2 : 1 : 5 : 0

λ-modes	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Σ(1/2-,j=0)	Σ(1/2-,j=1)	Σ(3/2-,j=1)	Σ(3/2-,j=2)	Σ(5/2-,j=2)
1 : 2	**0.004**	**0.010**	**0.007**	**0.015**	**0.007**	**0.038**	**0**
Rate(Yc)	**0.10**	**0.20**	**0.12**	**0.23**	**0.12**	**0.58**	**0**

ρ-modes	Λ(1/2-,j=0)	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Λ(3/2-,j=2)	Λ(5/2-,j=2)	Σ(1/2-,j=1)	Σ(3/2-,j=1)
Rate(Ys)	**0.017**	**0.039**	**0.018**	**0.10**	**0**	**0.016**	**0.032**
Rate(Yc)	**0.22**	**0.43**	**0.22**	**1.1**	**0**	**0.20**	**0.41**

1 : 2 : 1 : 5 : 0

1 : 2

- Neither one- nor two-quark process alone can explain experimental data
- Spin structure dependence has been found in λ- and ρ-mode productions

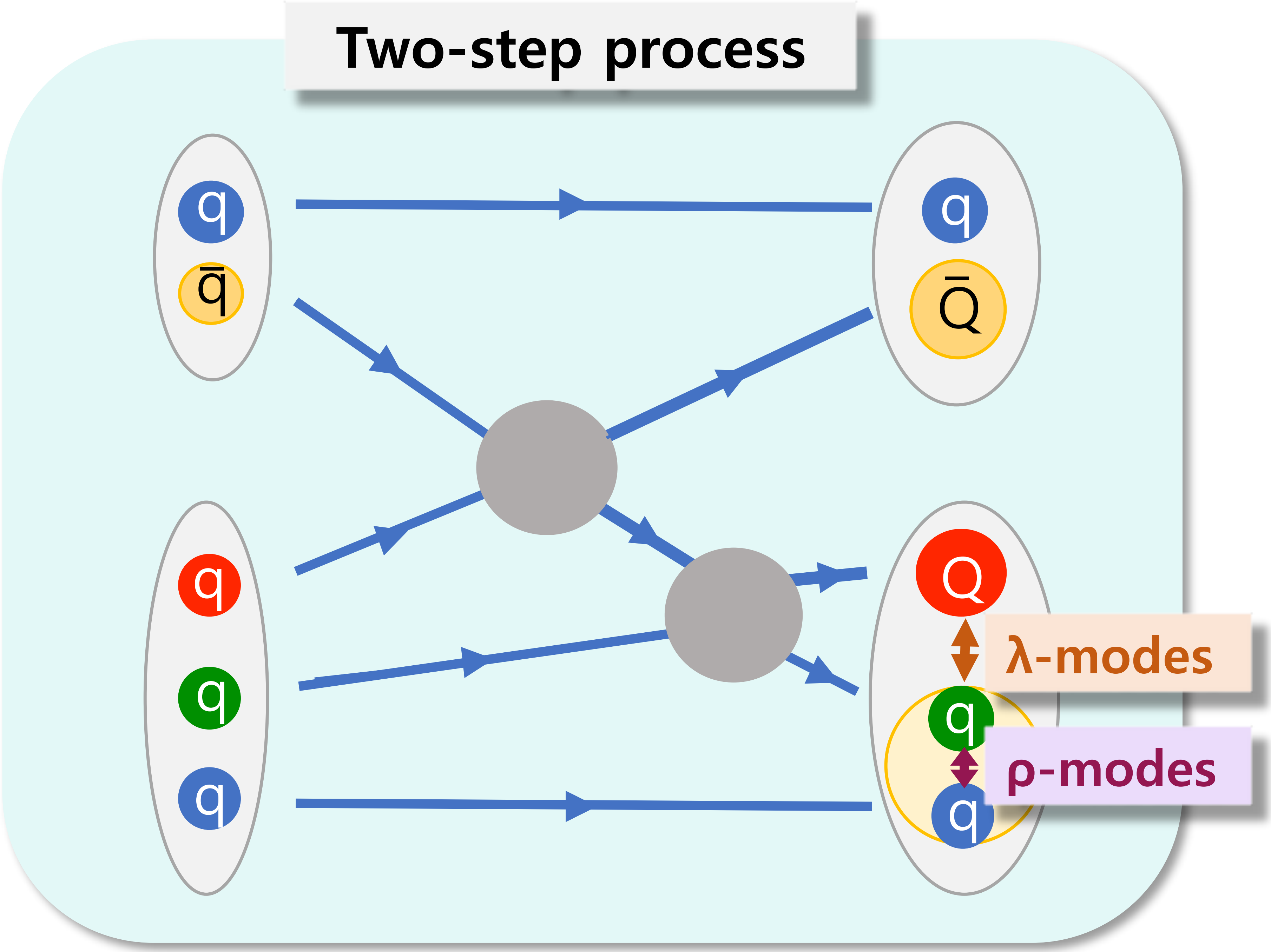
Summary

- Production rates of strange and charmed baryons are being studied with two-quark processes
- Momentum transfer & spin-structure dependences and ratio between G.S. Λ and Σ productions are discussed

Outlook

- Investigation for finite angles is planned
- Contributions from the both one-quark, two-quark and additional processes should be studied more
- Study on structure of the quark interaction is required to describe more realistic reactions

Heavy baryon productions from two-step processes



- Investigation on difference between one- and two-step processes
- Vector meson exchange processes can be possible $\pi^- p \to D^{*-}\Lambda_c^*$

Thank you for your attention!

Production rates(Preliminary)

G.S.	Λ(1/2+)	Σ(1/2+)	Σ(3/2+)
M(Ys)[1]	1116	1193	1385
M(Yc)[1]	2286	2453	2518
Rate(Ys)	1	3.3	0
Rate(Yc)	1	2.9	0

$\pi^-p \longrightarrow K^0 Y_s$ or $D^- Y_c$

$$|\vec{k}_\pi^{Lab}| = \begin{cases} 5 & \text{GeV for Strange} \\ 20 & \text{GeV for Charmed} \end{cases}$$

λ-modes	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Σ(1/2-,j=0)	Σ(1/2-,j=1)	Σ(3/2-,j=1)	Σ(3/2-,j=2)	Σ(5/2-,j=2)
M(Ys)[1,2]	1405	1520	1654	1734	1670	1755	1775
M(Yc)[2]	2595	2628	2802	2826	2807	2837	2839
Rate(Ys)	0.004	0.010	0.007	0.015	0.007	0.038	0
Rate(Yc)	0.10	0.20	0.12	0.23	0.12	0.58	0

ρ-modes	Λ(1/2-,j=0)	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Λ(3/2-,j=2)	Λ(5/2-,j=2)	Σ(1/2-,j=1)	Σ(3/2-,j=1)
M(Ys)[2]	1670	1777	1690	1810	1814	1751	1760
M(Yc)[2]	2890	2933	2917	2956	2960	2909	2910
Rate(Ys)	0.017	0.039	0.018	0.10	0	0.016	0.032
Rate(Yc)	0.22	0.43	0.22	1.1	0	0.20	0.41

[1] **PDG2016, Chinese Physics C, 40, 100001**

[2] **T. Yoshida, E. Hiyama, A. Hosaka, M. Oka, and K. Sadato, PhysRevD.92.114029(2015)**

Production rates(Preliminary)

$\pi^- p \longrightarrow K^0 Y_s$ or $D^- Y_c$

$$|\vec{k}_\pi^{Lab}| = \begin{cases} 5 & \text{GeV for Strange} \\ 20 & \text{GeV for Charmed} \end{cases}$$

G.S.	Λ(1/2+)	Σ(1/2+)	Σ(3/2+)
M(Ys)[1]	1116	1193	1385
M(Yc)[1]	2286	2453	2518
Rate(Ys)	1	3.3	0
Rate(Yc)	1	2.9	0

λ-modes	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Σ(1/2-,j=0)	Σ(1/2-,j=1)	Σ(3/2-,j=1)	Σ(3/2-,j=2)	Σ(5/2-,j=2)
M(Ys)[1,2]	1405	1520	1654	1734	1670	1755	1775
M(Yc)[2]	2595	2628	2802	2826	2807	2837	2839
Rate(Ys)	0.004	0.010	0.007	0.015	0.007	0.038	0
Rate(Yc)	0.10	0.20	0.12	0.23	0.12	0.58	0

ρ-modes	Λ(1/2-,j=0)	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Λ(3/2-,j=2)	Λ(5/2-,j=2)	Σ(1/2-,j=1)	Σ(3/2-,j=1)
M(Ys)[2]	1670	1777	1690	1810	1814	1751	1760
M(Yc)[2]	2890	2933	2917	2956	2960	2909	2910
Rate(Ys)	0.017	0.039	0.018	0.10	0	0.016	0.032
Rate(Yc)	0.22	0.43	0.22	1.1	0	0.20	0.41

[1] **PDG2016, Chinese Physics C, 40, 100001**

[2] **T. Yoshida, E. Hiyama, A. Hosaka, M. Oka, and K. Sadato, PhysRevD.92.114029(2015)**

Production rates(Preliminary)

G.S.	Λ(1/2+)	Σ(1/2+)	Σ(3/2+)
M(Ys)[1]	1116	1193	1385
M(Yc)[1]	2286	2453	2518
Rate(Ys)	1	3.3	0
Rate(Yc)	1	2.9	0

$\pi^-p \longrightarrow K^0 Y_s$ or $D^- Y_c$

$$|\vec{k}_\pi^{Lab}| = \begin{cases} 5 & \text{GeV for Strange} \\ 20 & \text{GeV for Charmed} \end{cases}$$

λ-modes	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Σ(1/2-,j=0)	Σ(1/2-,j=1)	Σ(3/2-,j=1)	Σ(3/2-,j=2)	Σ(5/2-,j=2)
M(Ys)[1,2]	1405	1520	1654	1734	1670	1755	1775
M(Yc)[2]	2595	2628	2802	2826	2807	2837	2839
Rate(Ys)	0.004	0.010	0.007	0.015	0.007	0.038	0
Rate(Yc)	0.10	0.20	0.12	0.23	0.12	0.58	0

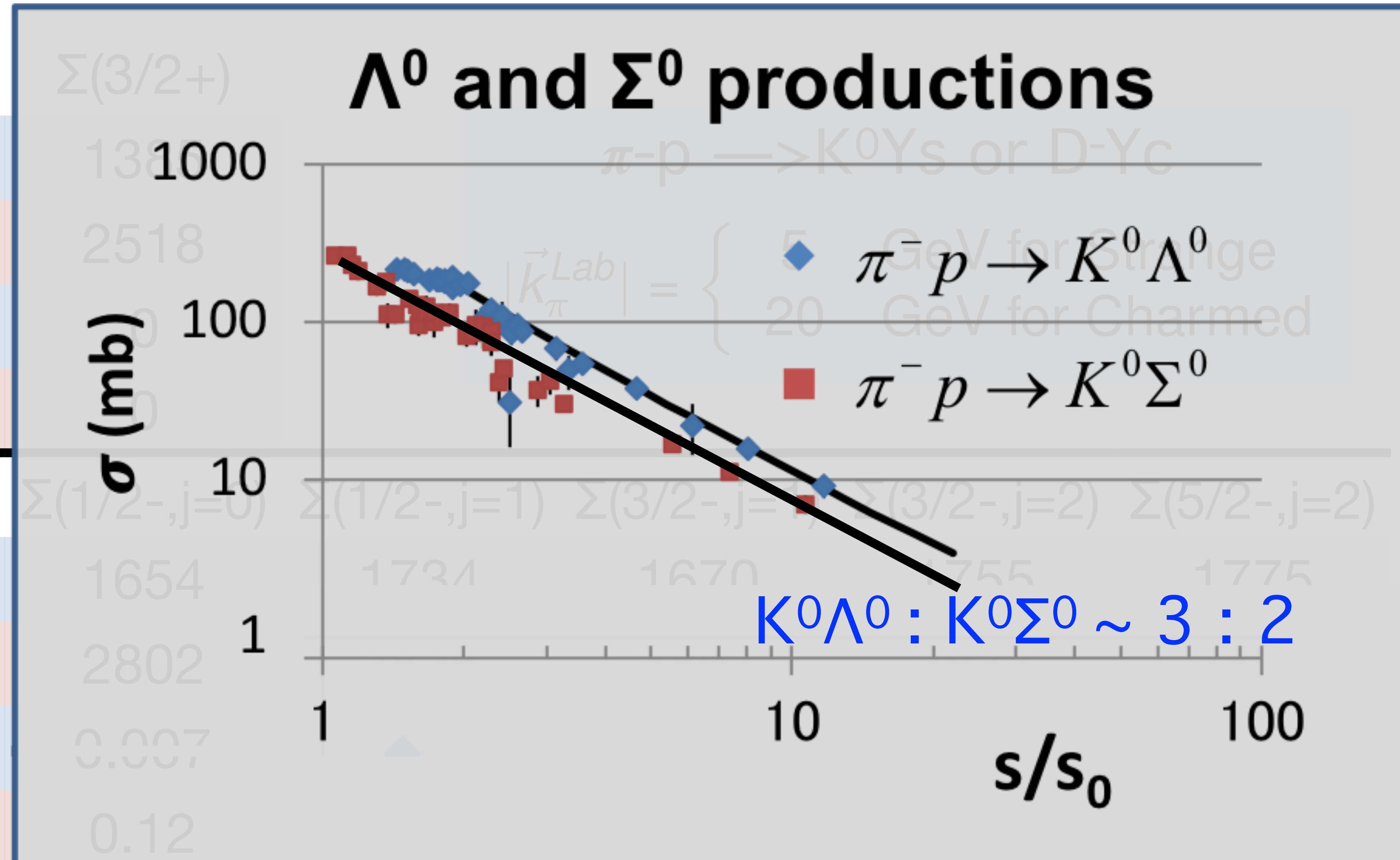
ρ-modes	Λ(1/2-,j=0)	Λ(1/2-,j=1)	Λ(3/2-,j=1)	Λ(3/2-,j=2)	Λ(5/2-,j=2)	Σ(1/2-,j=1)	Σ(3/2-,j=1)
M(Ys)[2]	1670	1777	1690	1810	1814	1751	1760
M(Yc)[2]	2890	2933	2917	2956	2960	2909	2910
Rate(Ys)	0.017	0.039	0.018	0.10	0	0.016	0.032
Rate(Yc)	0.22	0.43	0.22	1.1	0	0.20	0.41

[1] **PDG2016, Chinese Physics C, 40, 100001**

[2] **T. Yoshida, E. Hiyama, A. Hosaka, M. Oka, and K. Sadato, PhysRevD.92.114029(2015)**

Production rates(Preliminary)

G.S.	Λ(1/2+)	Σ(1/2+)
M(Ys)[1]	1116	1193
M(Yc)[1]	2286	2453
Rate(Ys)	1	3.3
Rate(Yc)	1	2.9
λ-modes	Λ(1/2-,j=1)	Λ(3/2-,j=1)
M(Ys)[1,2]	1405	1520
M(Yc)[2]	2595	2628
Rate(Ys)	0.004	0.010
Rate(Yc)	0.10	0.20



- Hyperon and charmed baryon productions show distinct differences on q^2_{eff} - dependence
- Spin structure dependence has been found in ρ- and λ-modes
- Both one- and two-quark processes need to be taken into account to explain experimental data