中国物理学会高能物理分会
第十二届全国会员代表大会暨学术年会

Study of the P_c and P_{cs} states

- Chu-Wen Xiao (肖楮文)
- Guangxi Normal University (广西师范大学)
- Collaborators： Jing-Zhi Cao , Huan-Yu Wei , Jiao-Xue Yang, Jian Sun

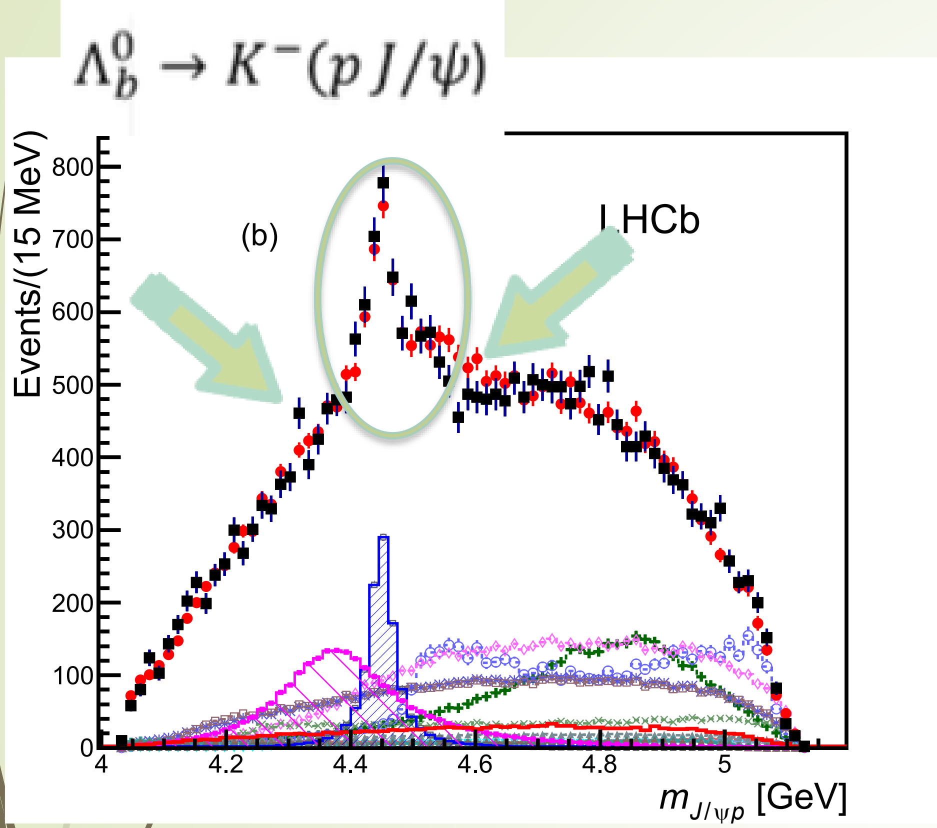
arXiv: 2604.04821

2026.7. 广州

Outline

1. Introduction
2. Formalism
3. Results
4. Summary

§1. Introduction



$P_c(4380)^+, \Gamma = 205$

$P_c(4450)^+, \Gamma = 39$

J^P ?

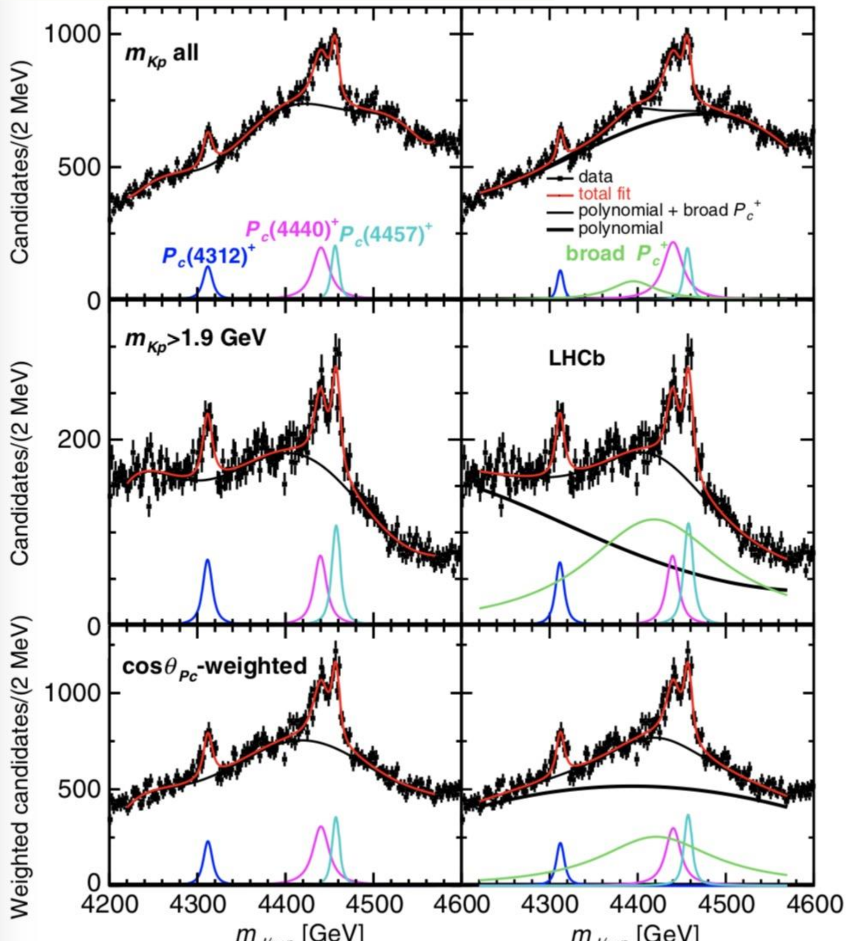
R. Aaij et al. (LHCb Collaboration), Phys. Rev. Lett. 115, 072001 (2015)

PHYSICAL REVIEW LETTERS **122**, 222001 (2019)

Featured in Physics

Observation of a Narrow Pentaquark State, $P_c(4312)^+$, and of the Two-Peak Structure of the $P_c(4450)^+$

R. Aaij *et al.*[*]
(LHCb Collaboration)



$$M_{P_{c1}} = 4311.9 \pm 0.7^{+6.8}_{-0.6}, \quad \Gamma_{P_{c1}} = 9.8 \pm 2.7^{+3.7}_{-4.5},$$
$$M_{P_{c2}} = 4440.3 \pm 1.3^{+4.1}_{-4.7}, \quad \Gamma_{P_{c2}} = 20.6 \pm 4.9^{+8.7}_{-10.1},$$
$$M_{P_{c3}} = 4457.3 \pm 0.6^{+4.1}_{-1.7}, \quad \Gamma_{P_{c3}} = 6.4 \pm 2.0^{+5.7}_{-1.9}.$$

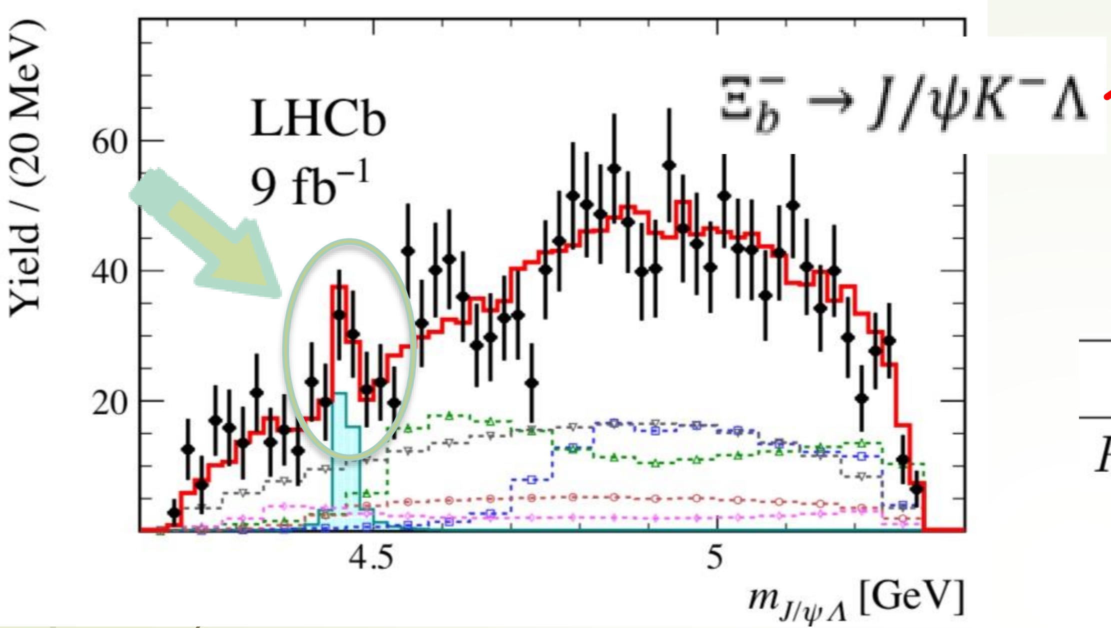
$P_c(4380)^+, \Gamma = 205$?

H.-X. Chen, W. Chen, X. Liu and S.-L. Zhu, Phys. Rept. 639, 1 (2016)
A. Esposito, A. Pilloni and A. D. Polosa, Phys. Rept. 668, 1 (2016)
A. Hosaka, T. Iijima, K. Miyabayashi, Y. Sakai and S. Yasui, PTEP 2016, 062C01 (2016)
H. X. Chen, W. Chen, X. Liu, Y. R. Liu and S. L. Zhu, Rept. Prog. Phys. 80, 076201 (2017)
R. F. Lebed, R. E. Mitchell and E. S. Swanson, Prog. Part. Nucl. Phys. 93, 143 (2017)
A. Ali, J. S. Lange and S. Stone, Prog. Part. Nucl. Phys. 97, 123 (2017)
F.-K. Guo, C. Hanhart, U.-G. Meißner, Q. Wang, Q. Zhao and B.-S. Zou, Rev. Mod. Phys. 90, 015004 (2018)
R. A. Briceño, J. J. Dudek and R. D. Young, Rev. Mod. Phys. 90, 025001 (2018)
S. L. Olsen, T. Skwarnicki and D. Zieminska, Rev. Mod. Phys. 90, 015003 (2018)
M. Karliner, J. L. Rosner and T. Skwarnicki, Ann. Rev. Nucl. Part. Sci. 68, 17 (2018)
C. Z. Yuan, Int. J. Mod. Phys. A 33,1830018 (2018)
Y. R. Liu, H. X. Chen, W. Chen, X. Liu and S. L. Zhu, Prog. Part. Nucl. Phys. 107, 237 (2019)
N. Brambilla, S. Eidelman, C. Hanhart, A. Nefediev, C. P. Shen, C. E. Thomas, A. Vairo and C. Z. Yuan, Phys. Rept. 873, 1 (2020)

Bing-Song Zou, Sci. Bull 66, 1258 (2021)

Findings for the Pcs state

H.-X. Chen, L.-S. Geng, W.-H. Liang, E. Oset, E. Wang, J.-J. Xie, Phys. Rev. C 93 (2016) 065203

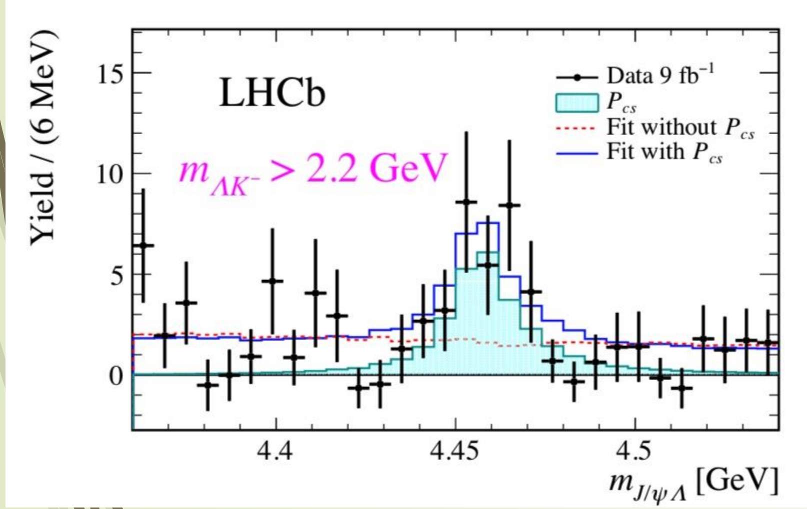


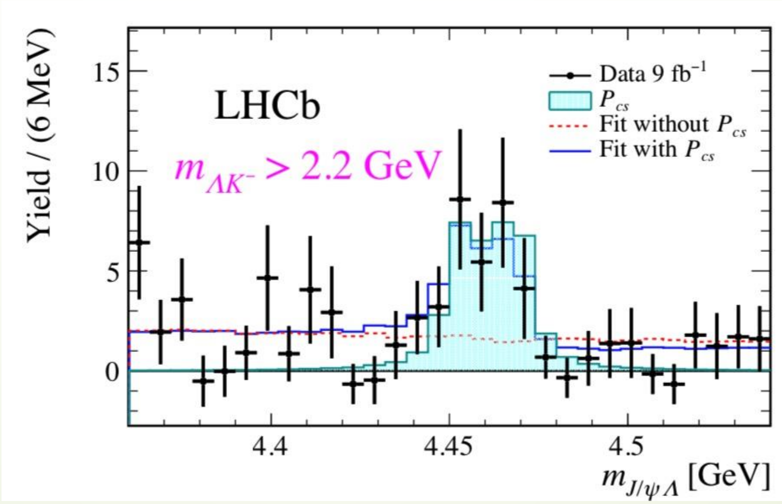
R. Aaij et al. (LHCb Collaboration), **Sci. Bull. 66** (2021) 1278-1287

State	M_0 [MeV]	Γ_0 [MeV]
$P_{cs}(4459)^0$	$4458.8 \pm 2.9\,^{+4.7}_{-1.1}$	$17.3 \pm 6.5\,^{+8.0}_{-5.7}$

J^P ?

mass difference of about 6 MeV





B. Wang, L. Meng and S. L. Zhu, **Phys. Rev. D 101** (2020) 034018.

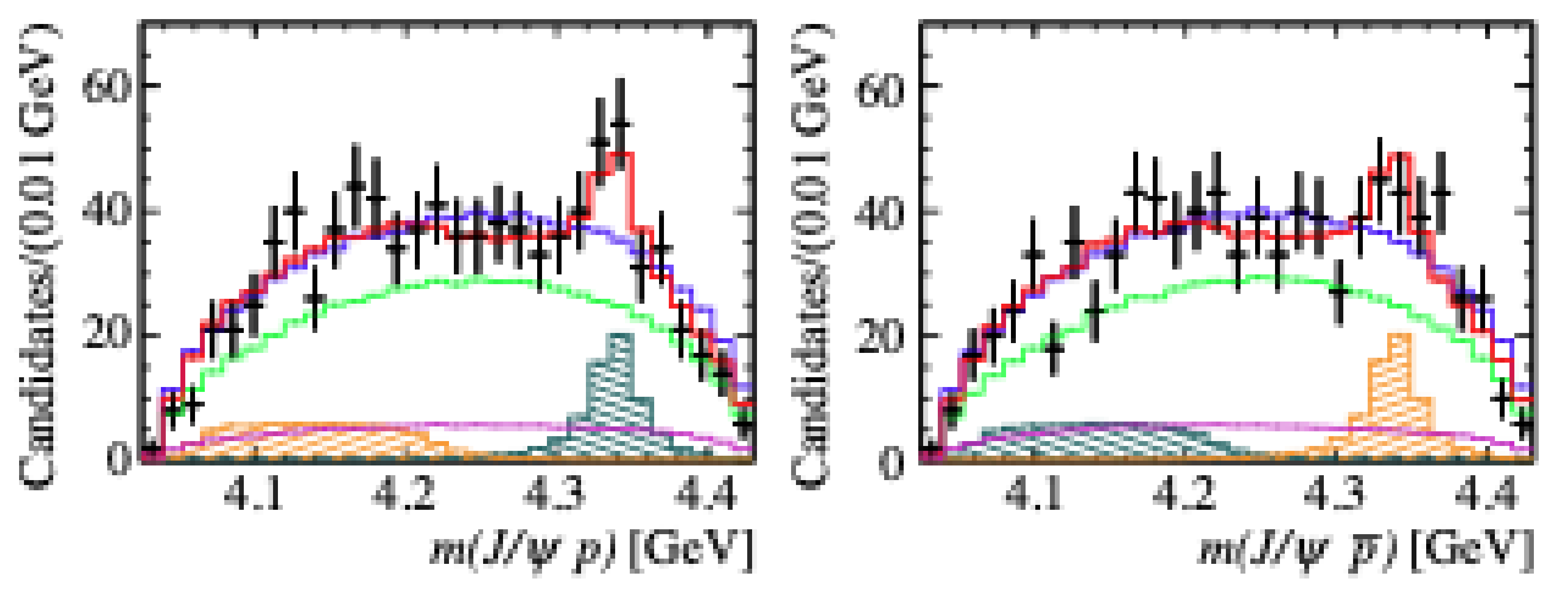
The data cannot confirm or refute the two-peak hypothesis.

PHYSICAL REVIEW LETTERS **128,** 062001 (2022)

Editors' Suggestion

Evidence for a New Structure in the $J/\psi p$ and $J/\psi\bar{p}$ Systems in $B_s^0 \to J/\psi p\bar{p}$ Decays

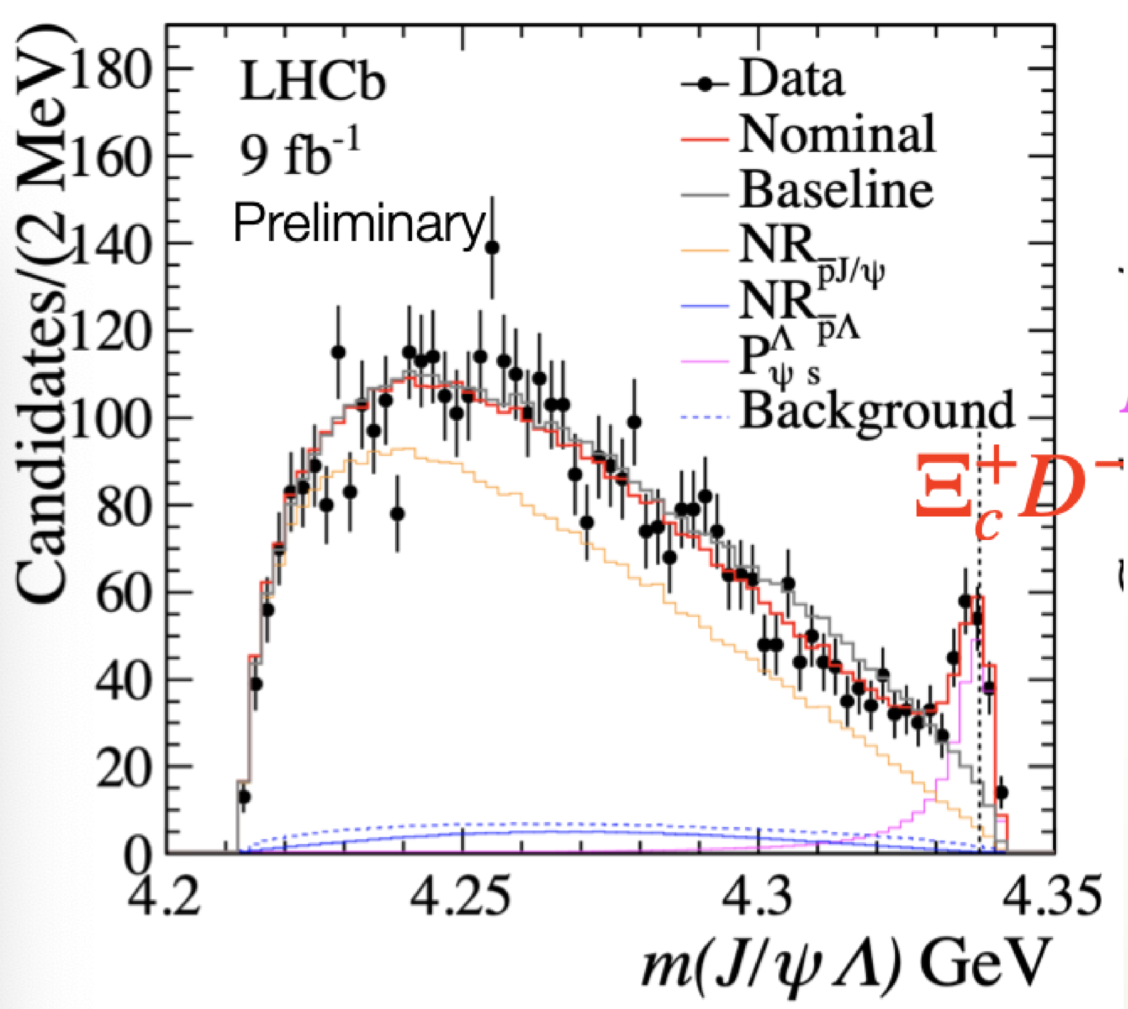
R. Aaij *et al.*[*]
(LHCb Collaboration)



$$M_{P_c} = 4337^{+7}_{-4}\,{}^{+2}_{-2}\ \text{MeV},$$

$$\Gamma_{P_c} = 29^{+26}_{-12}\,{}^{+14}_{-14}\ \text{MeV},$$

$B^- \to (J/\psi\Lambda)\bar{p}$



$m(P_{\psi s}^{\Lambda})$=4338.3±0.7±0.4 MeV

$\Gamma(P_{\psi s}^{\Lambda})$=7.0±1.2±1.3 MeV

$P_{\psi s}^{\Lambda}(4338)^0$

Significance: >10σ

LHCb, Phys. Rev. Lett. 131, 031901 (2023)

- $J = 1/2,\ I = 0$

$a_\mu(\mu = 1\ \text{GeV}) = -1.94$

Chan.	$\eta_c\Lambda$	$J/\psi\Lambda$	$\bar{D}\Xi_c$	$\bar{D}_s\Lambda_c$	$\bar{D}\Xi_c'$	$\bar{D}^*\Xi_c$	$\bar{D}_s^*\Lambda_c$	$\bar{D}^*\Xi_c'$	$\bar{D}^*\Xi_c^*$
Thres.	4099.58	4212.58	4336.61	4254.80	4445.34	4477.92	4398.66	4586.66	4654.48
$4310.53 + i8.23$	$P_{\psi s}^{\Lambda}(4338)^0$								
$\lvert g_i \rvert$	0.15	0.27	**2.33**	0.69	0.00	0.04	0.09	0.01	0.02
Γ_i	0.57	1.18	–	13.86					
Br.	3.47%	7.16%	–	84.21%					
$4445.12 + i0.19$									
$\lvert g_i \rvert$	0.10	0.06	0.00	0.00	**0.72**	0.08	0.04	0.01	0.01
Γ_i	0.29	0.08	0.00	0.00	–	–	0.04	–	–
Br.	74.74%	21.22%	0.01%	0.01%	–	–	10.62%	–	–
$4459.07 + i6.89$	$P_{cs}(4459)$								
$\lvert g_i \rvert$	0.22	0.13	0.00	0.00	0.07	**2.16**	0.61	0.03	0.02
Γ_i	1.59	0.46	0.00	0.00	0.01	–	11.14	–	–
Br.	11.57%	3.31%	0.00%	0.00%	0.70%	–	80.86%	–	–

F. L. Wang and X. Liu, **Phys. Lett. B 835,** 137583 (2022).

X.-W. Wang, Z.-G. Wang, Chin. Phys. C 47 (2023) 013109

L. Meng, B. Wang, S.-L. Zhu, Phys. Rev. D 107 (2023) 014005

J.-T. Zhu, S.-Y. Kong, J. He, Phys. Rev. D 107 (2023) 3, 034029

- $J = 3/2,\ I = 0$

H.-X. Chen, W. Chen, X. Liu, X.-H. Liu, Eur. Phys. J. C 81 (2021) 409

K. Azizi, Y. Sarac, H. Sundu, Phys. Rev. D 103 (2021) 094033

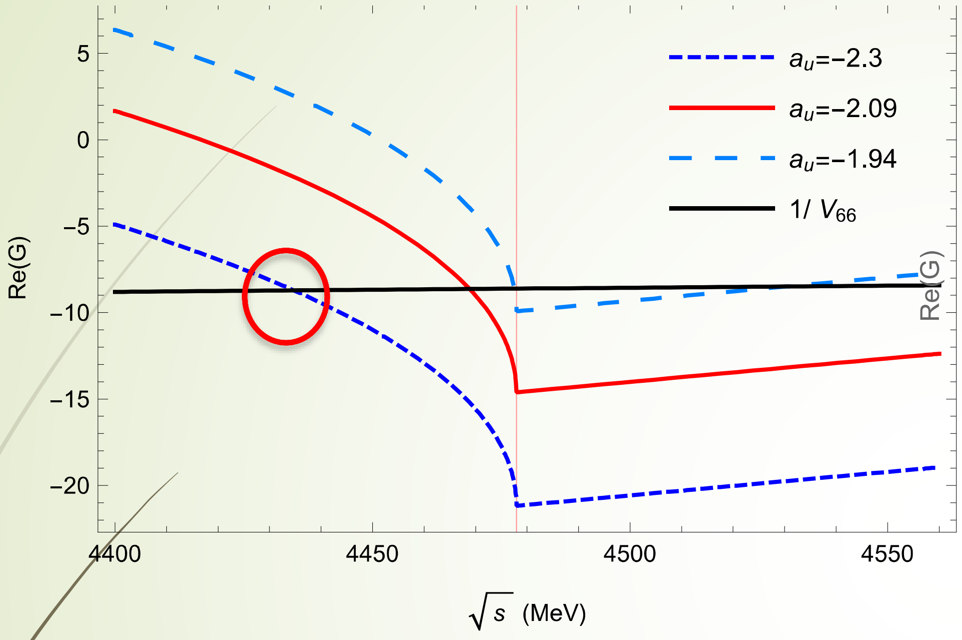
F.-Z. Peng, M.-J. Yan, M. Sánchez Sánchez, M.P. Valderrama, Eur. Phys. J. C 81 (2021) 666

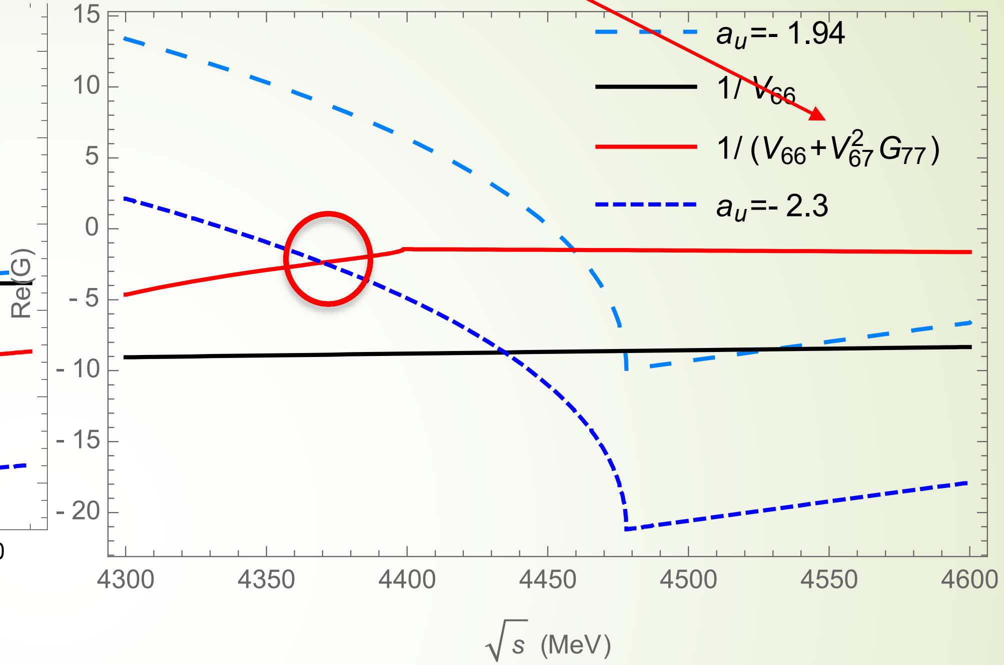
R. Chen, Phys. Rev. D 103 (2021) 054007

M.-Z. Liu, Y.-W. Pan, L.-S. Geng, Phys. Rev. D 103 (2021) 034003

W.-Y. Liu, W. Hao, G.-Y. Wang, Y.-Y. Wang, E. Wang, D.-M. Li, Phys. Rev. D 103 (2021) 034019 for the $\bar{D}^*\Xi_c$ channel

$\bar{D}_s^*\Lambda_c$





	$J/\psi\Lambda$	$\bar{D}_s^*\Lambda_c$	$\bar{D}^*\Xi_c$	$\bar{D}^*\Xi_c'$
$J/\psi\Lambda$	0	$-\frac{1}{\sqrt{3}}\lambda$	$\frac{1}{\sqrt{6}}\lambda$	$-\frac{1}{\sqrt{2}}\lambda$
$\bar{D}_s^*\Lambda_c$		0	$-\sqrt{2}$	0
$\bar{D}^*\Xi_c$			-1	0
$\bar{D}^*\Xi_c'$				-1

$\bar{D}\Xi_c$ $\bar{D}_s\Lambda_c$

CWX, J. J. Wu and B. S. Zou, Phys. Rev. D 103 (2021) 054016.

Noting the results for Pc

$$
\begin{array}{ccccccc}
\eta_c N & J/\psi N & \bar{D}\Lambda_c & \bar{D}\Sigma_c & \bar{D}^*\Lambda_c & \bar{D}^*\Sigma_c & \bar{D}^*\Sigma_c^* \\
\end{array}
$$

$$
\begin{pmatrix}
\mu_1 & 0 & \frac{\mu_{12}}{2} & \frac{\mu_{13}}{2} & \frac{\sqrt{3}\mu_{12}}{2} & -\frac{\mu_{13}}{2\sqrt{3}} & \sqrt{\frac{2}{3}}\mu_{13} \\
0 & \mu_1 & \frac{\sqrt{3}\mu_{12}}{2} & -\frac{\mu_{13}}{2\sqrt{3}} & -\frac{\mu_{12}}{2} & \frac{5\mu_{13}}{6} & \frac{\sqrt{2}\mu_{13}}{3} \\
\frac{\mu_{12}}{2} & \frac{\sqrt{3}\mu_{12}}{2} & \mu_2 & 0 & 0 & \frac{\mu_{23}}{\sqrt{3}} & \sqrt{\frac{2}{3}}\mu_{23} \\
\frac{\mu_{13}}{2} & -\frac{\mu_{13}}{2\sqrt{3}} & 0 & \frac{1}{3}(2\lambda_2+\mu_3) & \frac{\mu_{23}}{\sqrt{3}} & \frac{2(\lambda_2-\mu_3)}{3\sqrt{3}} & \frac{1}{3}\sqrt{\frac{2}{3}}(\mu_3-\lambda_2) \\
\frac{\sqrt{3}\mu_{12}}{2} & -\frac{\mu_{12}}{2} & 0 & \frac{\mu_{23}}{\sqrt{3}} & \mu_2 & -\frac{2\mu_{23}}{3} & \frac{\sqrt{2}\mu_{23}}{3} \\
-\frac{\mu_{13}}{2\sqrt{3}} & \frac{5\mu_{13}}{6} & \frac{\mu_{23}}{\sqrt{3}} & \frac{2(\lambda_2-\mu_3)}{3\sqrt{3}} & -\frac{2\mu_{23}}{3} & \frac{1}{9}(2\lambda_2+7\mu_3) & \frac{1}{9}\sqrt{2}(\mu_3-\lambda_2) \\
\sqrt{\frac{2}{3}}\mu_{13} & \frac{\sqrt{2}\mu_{13}}{3} & \sqrt{\frac{2}{3}}\mu_{23} & \frac{1}{3}\sqrt{\frac{2}{3}}(\mu_3-\lambda_2) & \frac{\sqrt{2}\mu_{23}}{3} & \frac{1}{9}\sqrt{2}(\mu_3-\lambda_2) & \frac{1}{9}(\lambda_2+8\mu_3)
\end{pmatrix}_{I=1/2}
$$

$$
\mu_1 = 0, \quad \mu_{23} = 0, \quad \lambda_2 = \mu_3, \quad \mu_{13} = -\mu_{12},
$$

$$
\mu_2 = \frac{1}{4f^2}(k^0 + k'^0), \quad \mu_3 = -\frac{1}{4f^2}(k^0 + k'^0),
$$

CWX, J. Nieves and E. Oset, Phys. Rev. D 100 (2019) 014021

Further investigation

$PB(1/2^+)$ sector with $J^P = \frac{1}{2}^-$

Poles		$\eta_c\Lambda$	$\bar{D}_s\Lambda_c$	$\bar{D}\Xi_c$	$\bar{D}\Xi'_c$
$\boxed{4198.94 + i0.11}$	g_i	$0.12 - i0.00$	$3.01 - i0.01$	**4.85+i0.01**	$0.01 - i0.03$
	$g_iG_i^{II}$	$-0.35 + i1.01$	$-19.24 + i0.05$	**−20.35−i0.07**	$-0.03 + i0.09$
→ $4422.79 + i7.75$	g_i	$0.71 - i0.08$	$0.05 + i0.00$	$-0.06 + i0.04$	**2.79−i0.35**
	$g_iG_i^{II}$	$1.14 + i10.71$	$0.76 + i1.82$	$-0.43 - i1.53$	**−26.54+i0.64**

$P_{cs}(4459)$

$VB(1/2^+)$ sector with $J^P = \frac{1}{2}^-, \frac{3}{2}^-$

Poles		$J/\psi\Lambda$	$\bar{D}_s^*\Lambda_c$	$\bar{D}^*\Xi_c$	$\bar{D}^*\Xi'_c$
→ $\boxed{4337.98 + i0.12}$	g_i	$0.11 - i0.00$	$3.17 - i0.01$	**5.07+i0.01**	$0.00 - i0.04$
	$g_iG_i^{II}$	$-0.13 + i1.07$	$-18.57 + i0.06$	**−19.94−i0.07**	$-0.01 + i0.10$
$4565.73 + i15.58$	g_i	$0.70 - i0.16$	$0.09 - i0.03$	$-0.10 + i0.09$	**2.84−i0.72**
	$g_iG_i^{II}$	$6.24 + i21.04$	$2.07 + i3.40$	$-1.37 - i2.81$	**−26.31+i1.15**

$P_{\psi s}^{\Lambda}(4338)^0$

$P_c : \bar{D}\Sigma_c, \bar{D}\Lambda_c$ and $\bar{D}^*\Sigma_c, \bar{D}^*\Lambda_c$

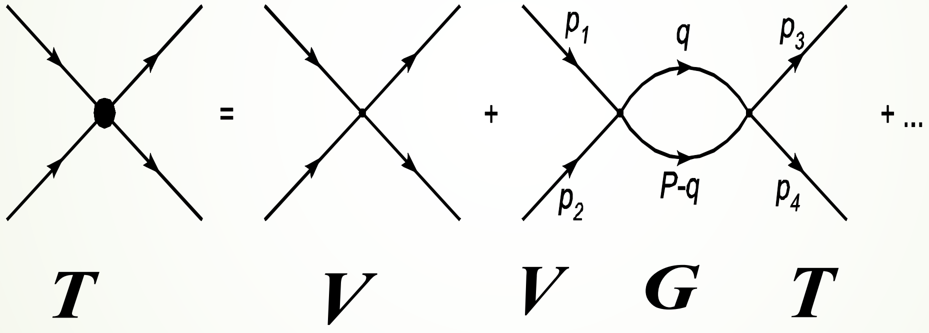
$\cancel{P_{cs} : \bar{D}\Xi_c, \bar{D}_s\Lambda_c \text{ and } \bar{D}^*\Xi_c, \bar{D}_s^*\Lambda_c}$

A. Feijoo, W. F. Wang, **CWX**, J. J. Wu, E. Oset, J. Nieves, B. S. Zou, Phys. Lett. B 839 (2023) 137760

§2. Formalism

➨ **Coupled Channel Unitary Approach**： solving Bethe-Salpeter equations, which take on-shell approximation for the loops.

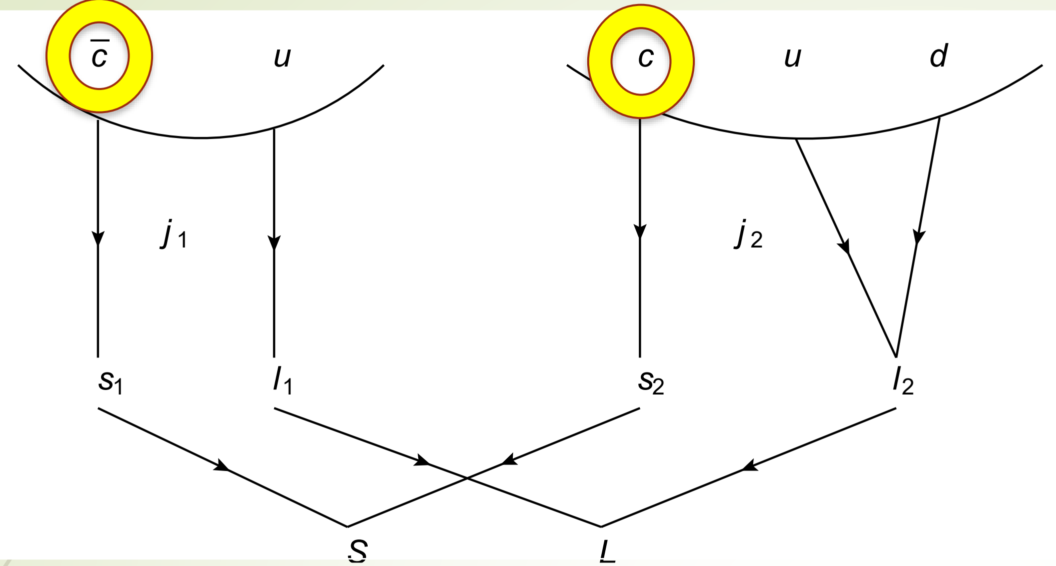
$$T = V + V\,G\,T,\; T = [1 - V\,G]^{-1}\,V$$



D. L. Yao, L. Y. Dai, H. Q. Zheng and Z. Y. Zhou, Rept. Prog. Phys. 84, 076201 (2021)

where V matrix (potentials) can be evaluated from the interaction Lagrangians.

J. A. Oller and E. Oset, Nucl. Phys. A 620 (1997) 438
E. Oset and A. Ramos, Nucl. Phys. A 635 (1998) 99
J. A. Oller and U. G. Meißner, Phys. Lett. B 500 (2001) 263



Considering the heavy quark spin symmetry

$$\bar{D} \longrightarrow \bar{D}^*$$

$$\Sigma_c \longrightarrow \Sigma_c^*$$

$$\Xi_c \longrightarrow \Xi_c^*$$

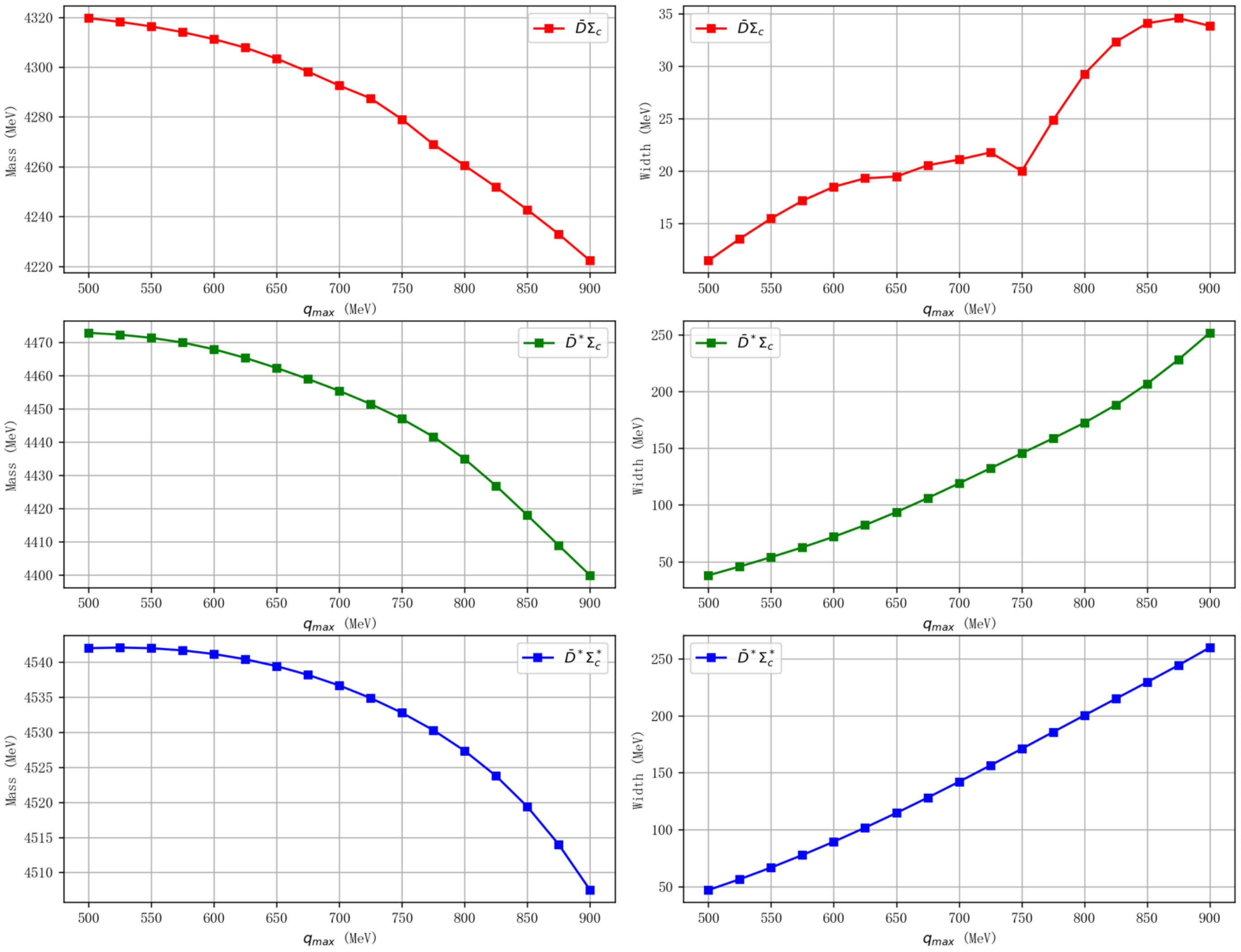
$$\boxed{{}_{(\ell'_M\ell'_B S')}\langle S'_{c\bar{c}}\mathcal{L}';\, J'\,|H^{QCD}|S_{c\bar{c}}\mathcal{L};\, J,\,\rangle_{(\ell_M\ell_B S)} = \delta_{JJ'}\delta_{S'_{c\bar{c}}S_{c\bar{c}}}\delta_{\mathcal{L}\mathcal{L}'}\langle \ell'_M\ell'_B S'||H^{QCD}||\ell_M\ell_B S\rangle_{\mathcal{L}}}$$

$$|\ell_M s_M j_M S;\, \ell_B s_B j_B;\, J\rangle = \sum_{\mathcal{L},S_{c\bar{c}}} [(2S_{c\bar{c}}+1)(2\mathcal{L}+1)(2j_M+1)(2j_B+1)]^{\frac{1}{2}} \times \begin{Bmatrix} \ell_M & \ell_B & \mathcal{L} \\ s_M & s_B & S_{c\bar{c}} \\ j_M & j_B & J \end{Bmatrix} |\mathcal{L}S_{c\bar{c}};\, J\rangle_{(\ell_M\ell_B S)}$$

X. K. Dong, F. K. Guo and B. S. Zou, *Progr. Phys.* 41 (2021) 65; *Commun. Theor. Phys.* 73 (2021) 125201.

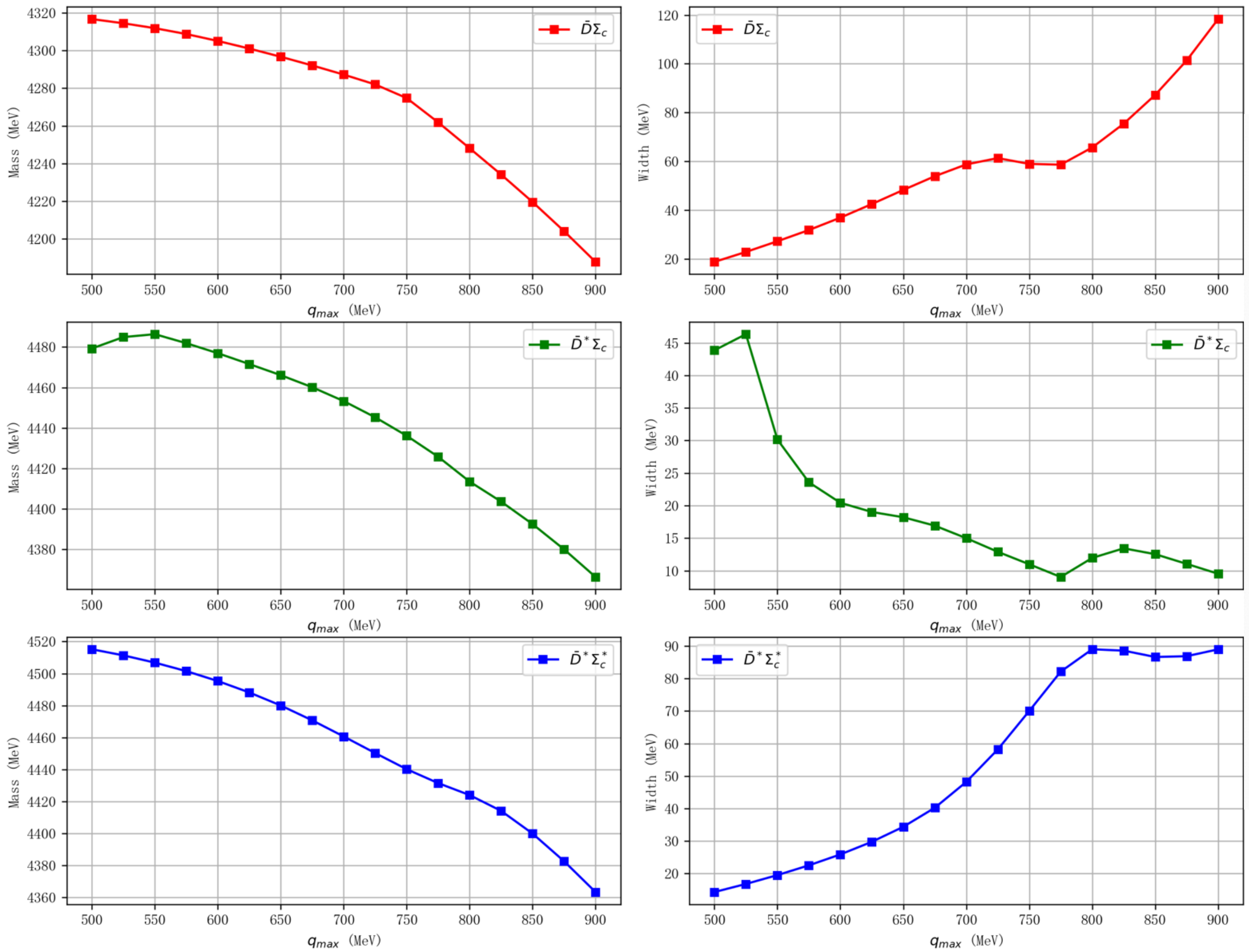
§3. Results-1

(1) $J^P = 1/2^-$ Pc poles: full coupled channels



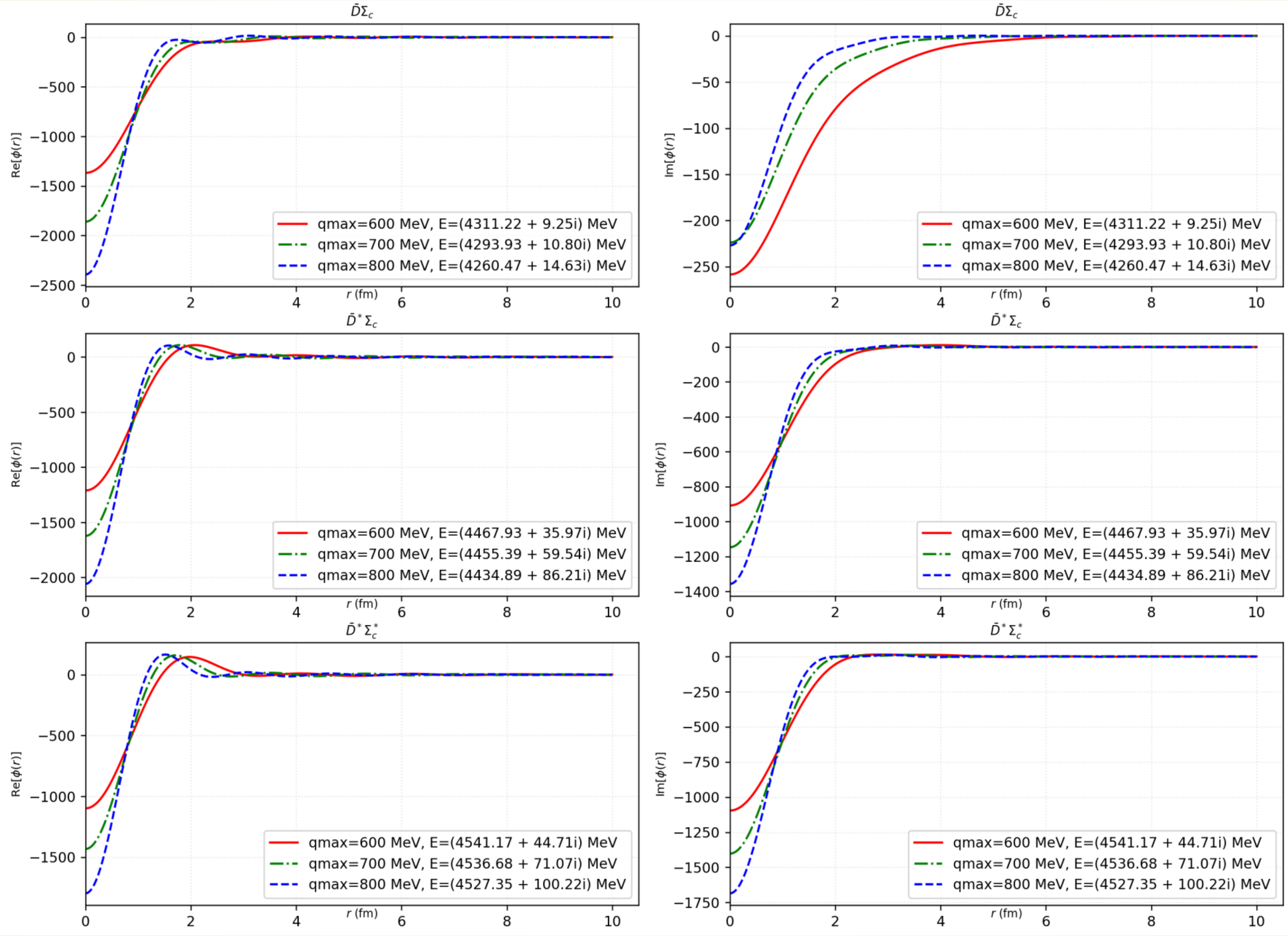
q_{max} [MeV]	Mass [MeV]	Width [MeV]	Main channel	J^P	Experimental states
600	4311.22	18.50	$\bar{D}\Sigma_c$	$1/2^-$	$P_c(4312)$
700	4293.93	21.60	$\bar{D}\Sigma_c$	$1/2^-$	
800	4260.47	29.26	$\bar{D}\Sigma_c$	$1/2^-$	
600	4467.93	71.95	$\bar{D}^*\Sigma_c$	$1/2^-$	
700	4455.39	119.08	$\bar{D}^*\Sigma_c$	$1/2^-$	$P_c(4440)$
800	4434.89	172.42	$\bar{D}^*\Sigma_c$	$1/2^-$	
600	4541.17	89.41	$\bar{D}^*\Sigma_c^*$	$1/2^-$	–
700	4536.68	142.14	$\bar{D}^*\Sigma_c^*$	$1/2^-$	–
800	4527.35	200.45	$\bar{D}^*\Sigma_c^*$	$1/2^-$	–

Pc poles : PB and VB sectors

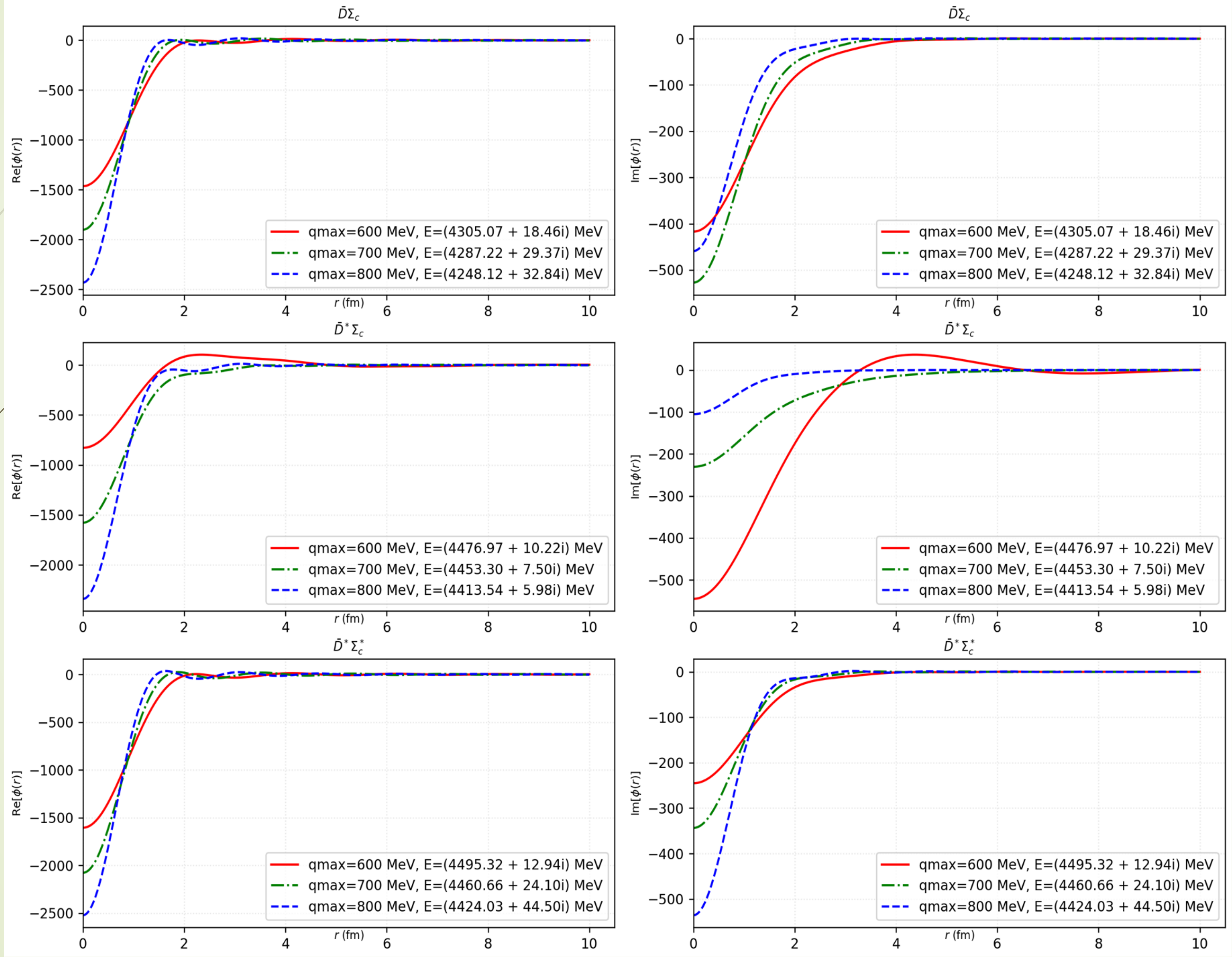


q_{max} [MeV]	Mass [MeV]	Width [MeV]	Main channel	Sector	J^P	Experimental states
600	4305.07	36.92	$\bar{D}\Sigma_c$	PB	$1/2^-$	$P_c(4312)$
700	4287.22	58.75	$\bar{D}\Sigma_c$	PB	$1/2^-$	
800	4248.12	65.69	$\bar{D}\Sigma_c$	PB	$1/2^-$	
600	4476.97	20.44	$\bar{D}^*\Sigma_c$	VB	$1/2^-$	
700	4453.30	15.00	$\bar{D}^*\Sigma_c$	VB	$1/2^-$	$P_c(4440)$
800	4413.54	11.96	$\bar{D}^*\Sigma_c$	VB	$1/2^-$	
600	4495.32	25.88	$\bar{D}^*\Sigma_c^*$	VB	$1/2^-$	–
700	4460.66	48.19	$\bar{D}^*\Sigma_c^*$	VB	$1/2^-$	–
800	4424.03	89.01	$\bar{D}^*\Sigma_c^*$	VB	$1/2^-$	–

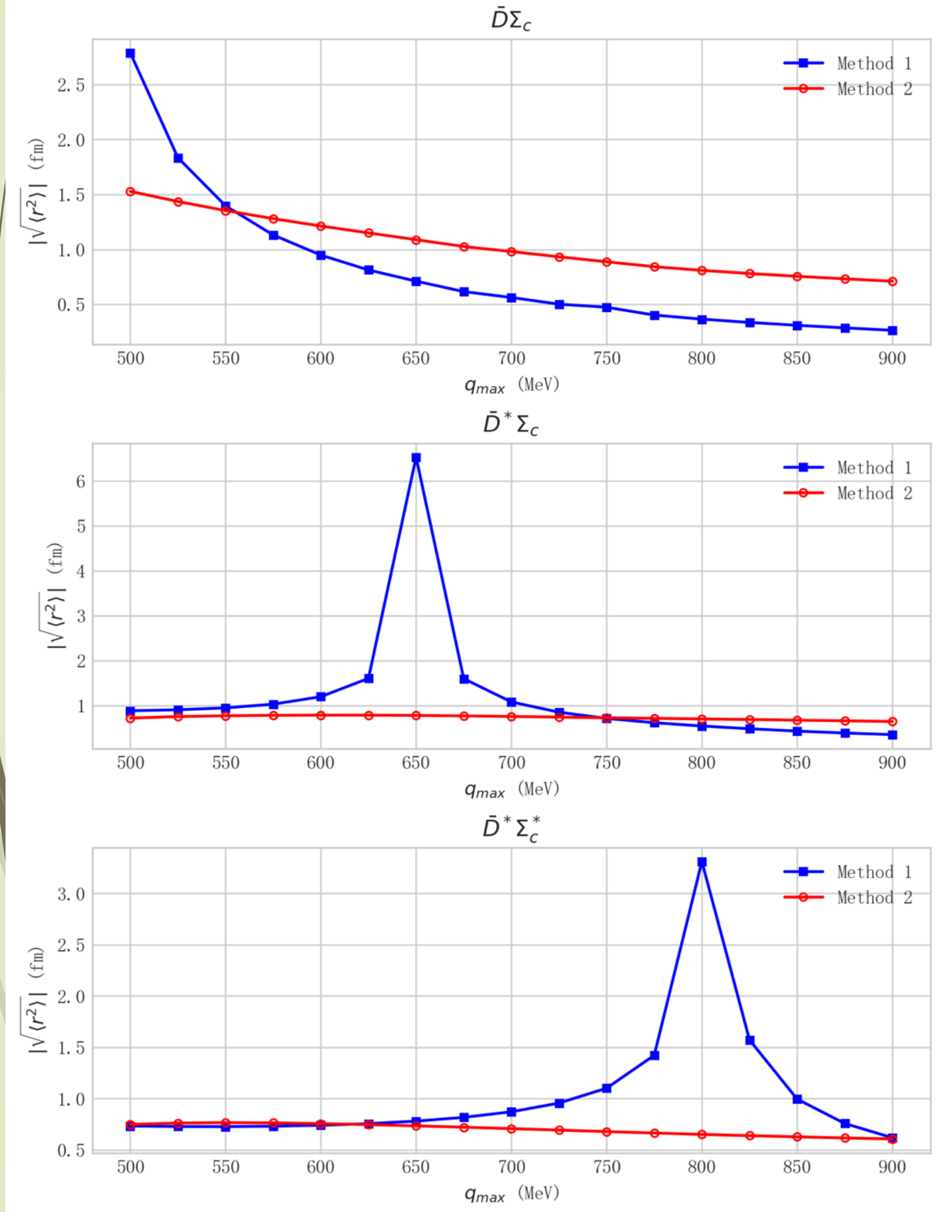
(2) Pc wave functions : full coupled channels



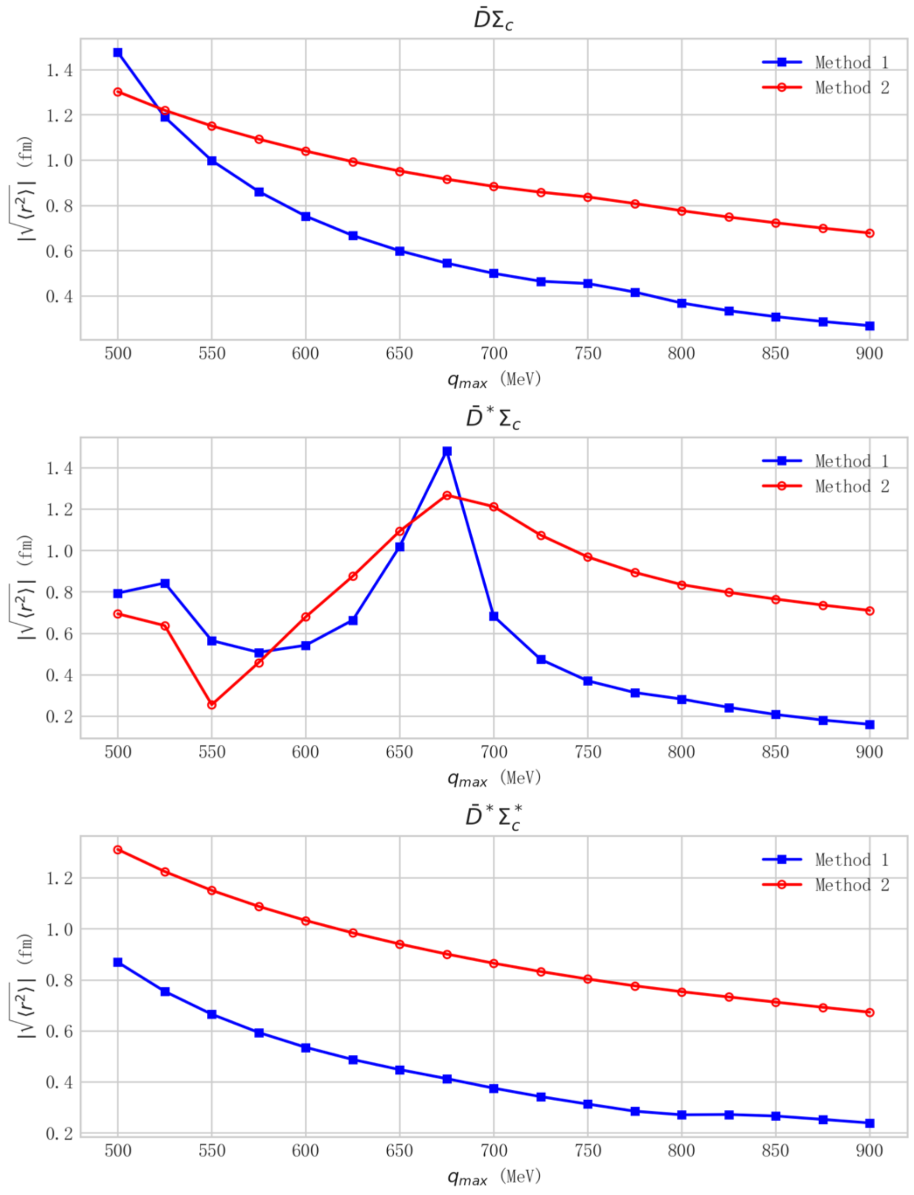
Pc wave functions : PB and VB sectors



(3) Pc radii: full coupled channels

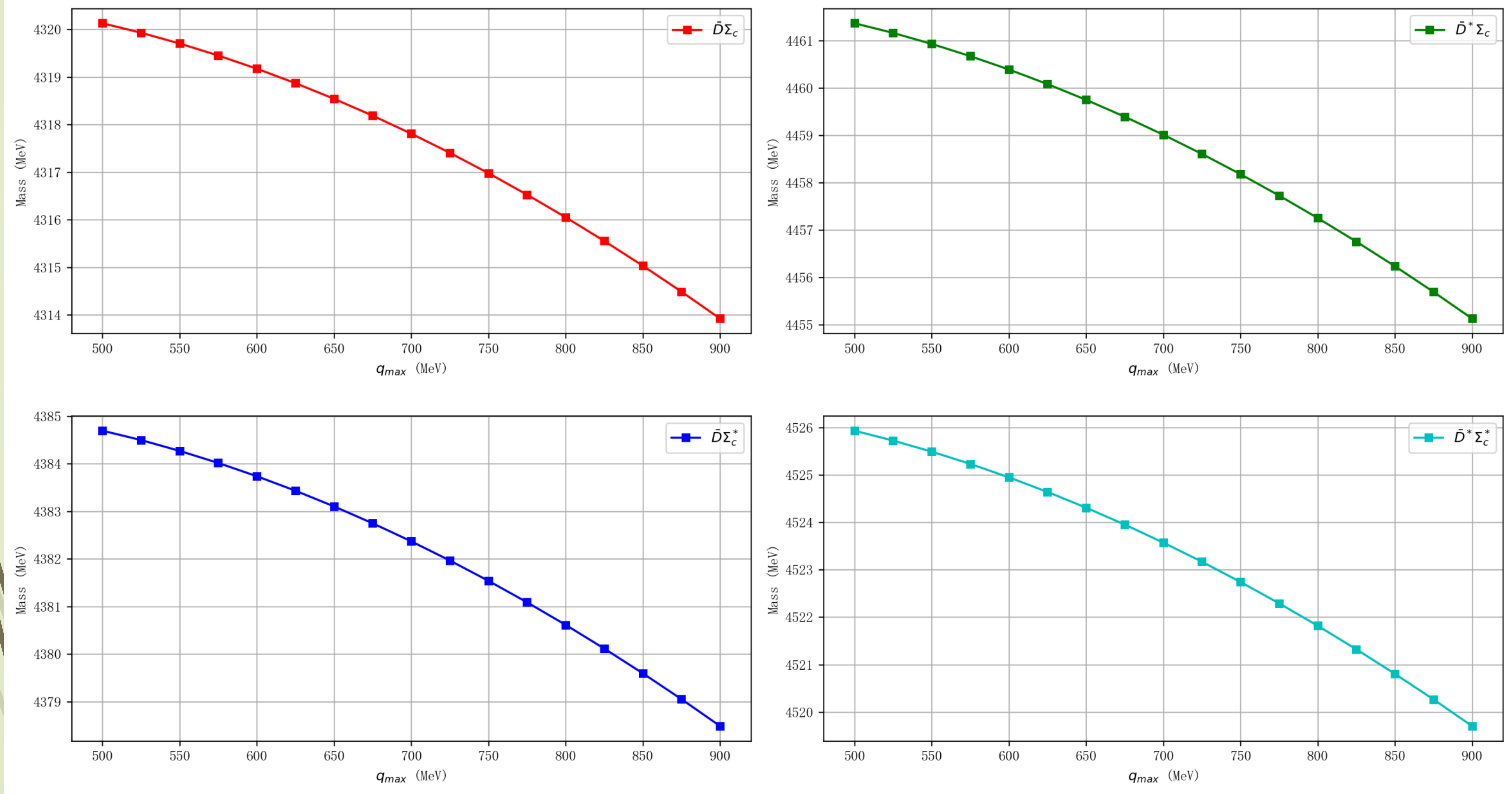


PB and VB sectors

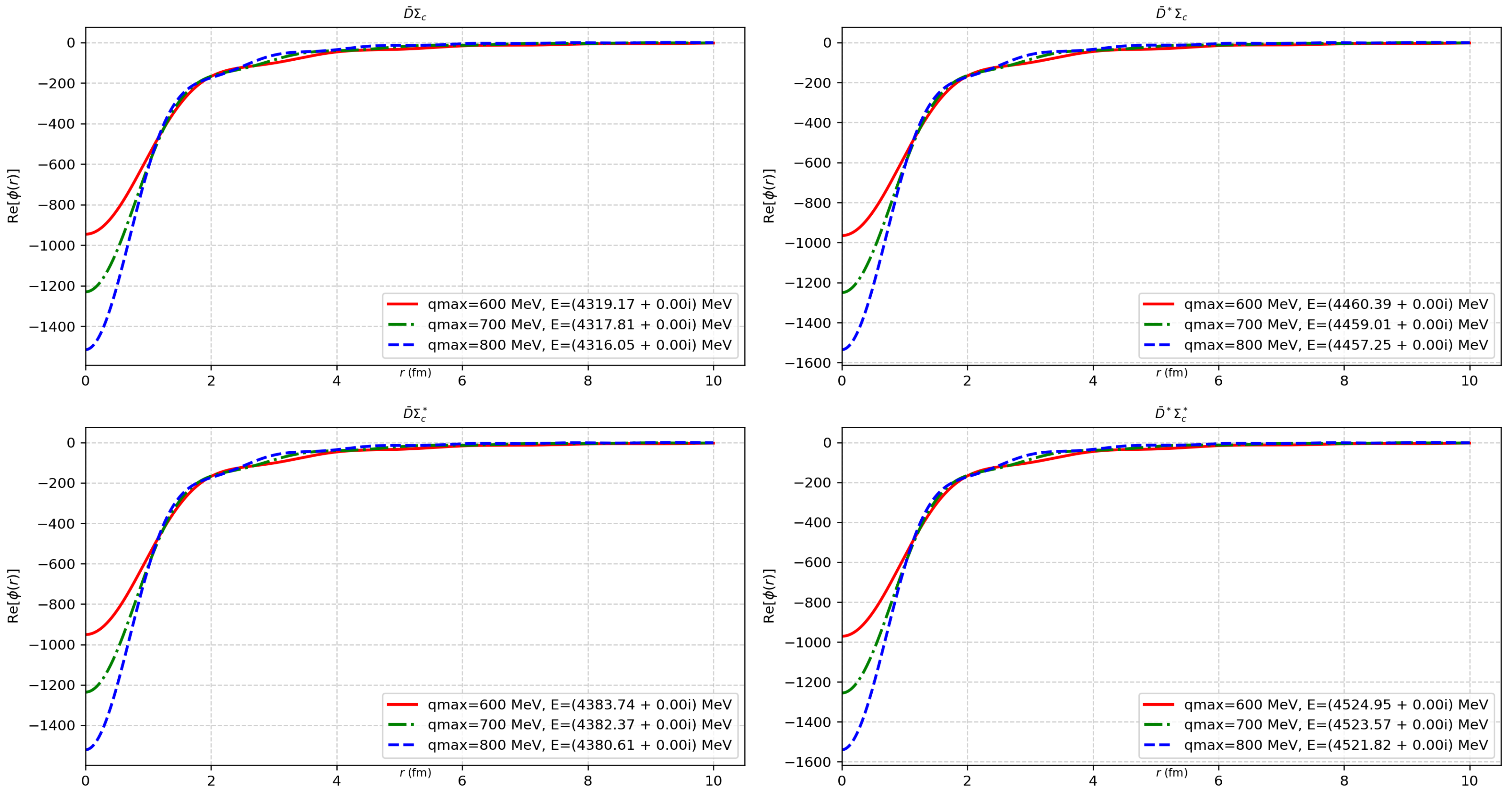


(4) Single *channel interaction* poles:

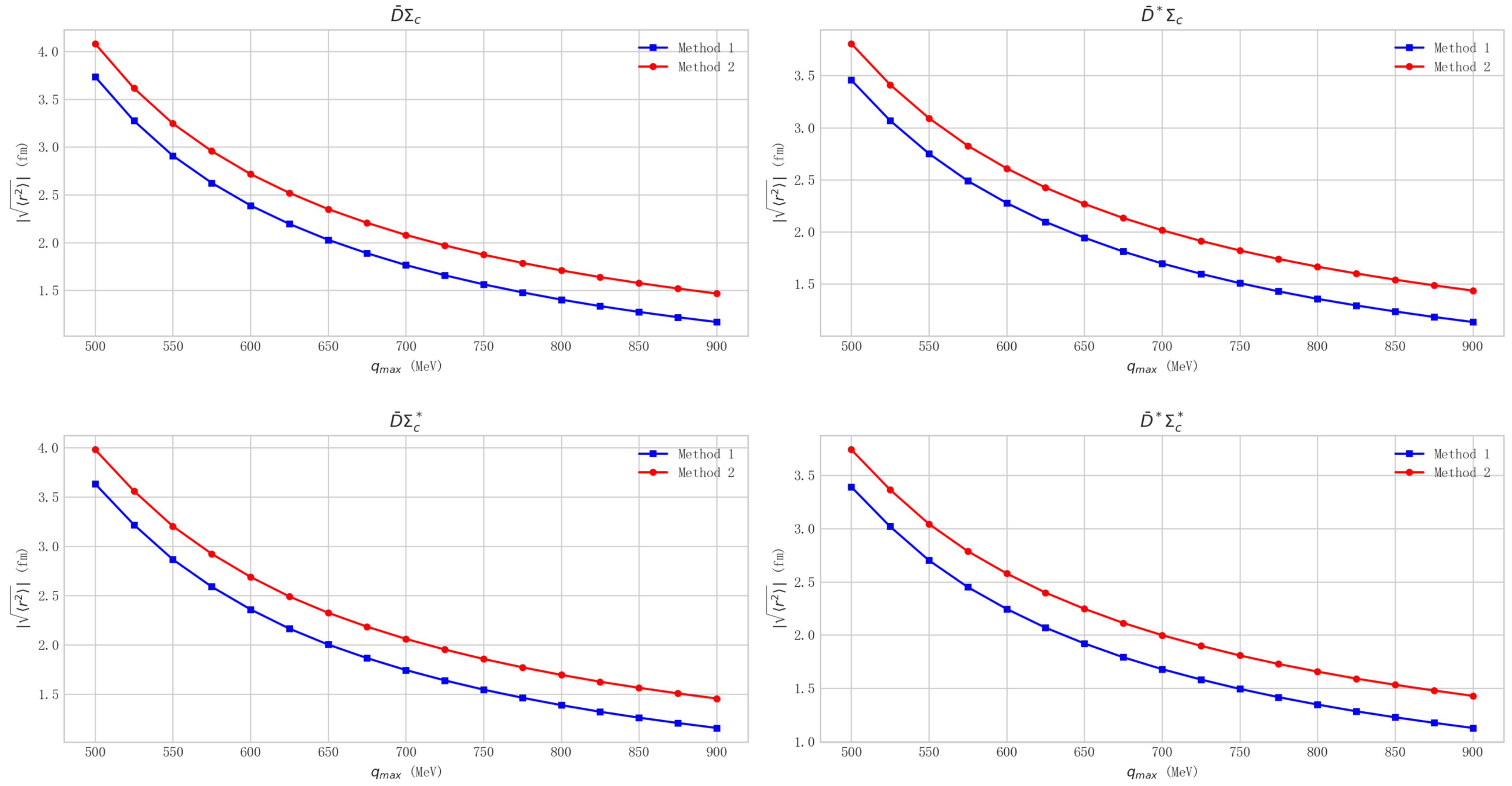
$J^P = 3/2^-$ *Pc states*



Wave functions:



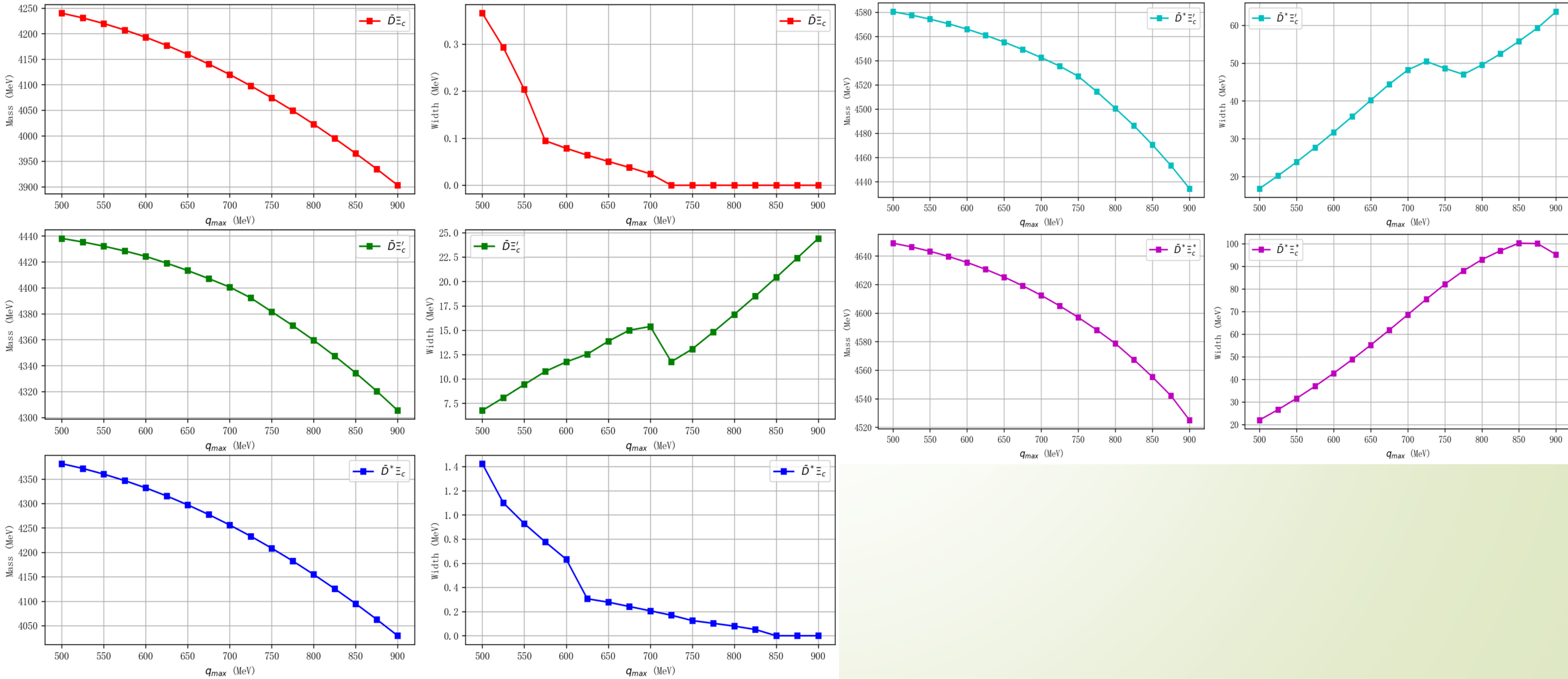
Radii:



$\bar{D}\Sigma_c$
$\bar{D}^*\Sigma_c$
$\bar{D}\Sigma_c^*$
$\bar{D}^*\Sigma_c^*$
Method 1
Method 2
$|\sqrt{\langle r^2\rangle}|$ (fm)
q_{max} (MeV)
500
550
600
650
700
750
800
850
900
1.0
1.5
2.0
2.5
3.0
3.5
4.0

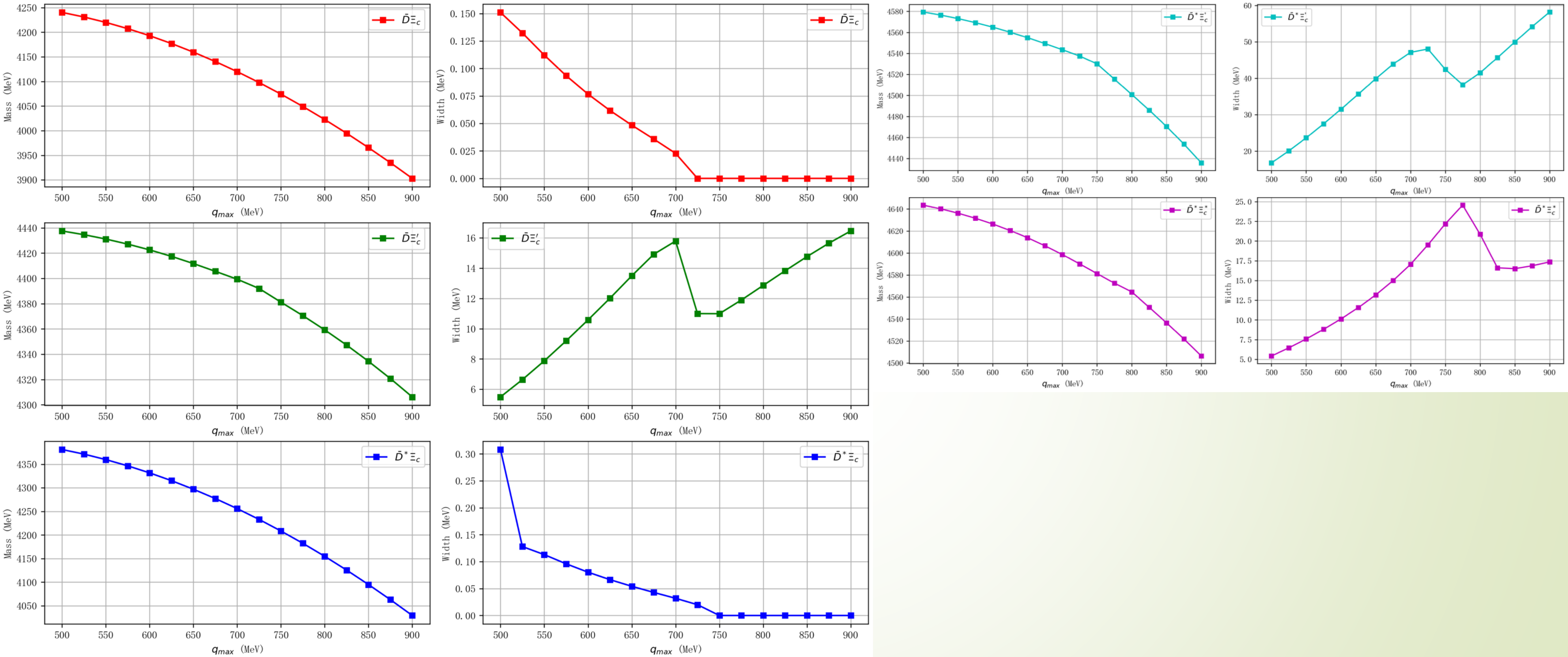
§3. Results-2

(1) $J^P = 1/2^-$ Pcs poles: full coupled channels



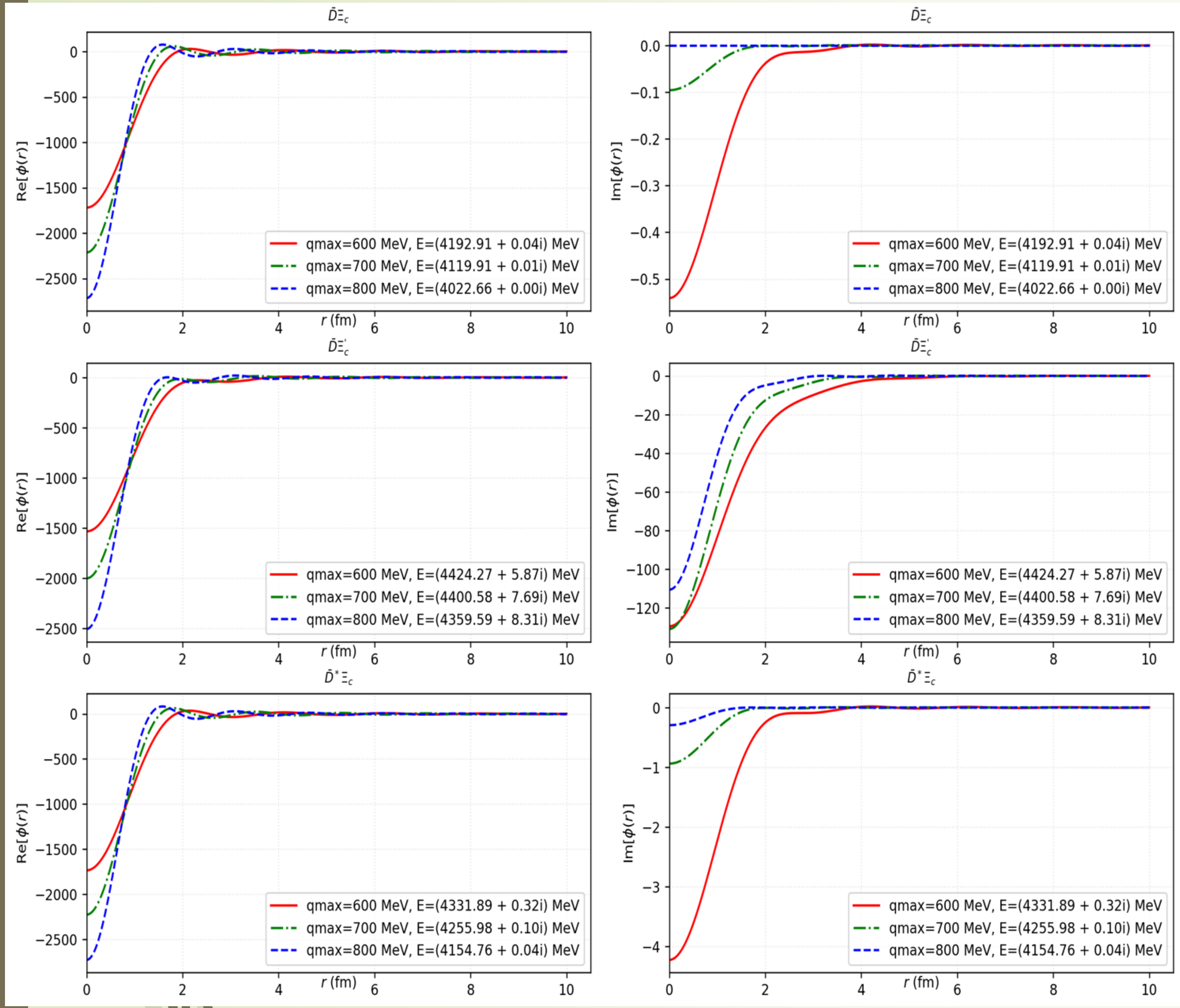
q_{max} [MeV]	Mass [MeV]	Width [MeV]	Main channel	J^P	Experimental states
600	4192.91	0.08	$\bar{D}\Xi_c$	$1/2^-$	–
700	4119.91	0.02	$\bar{D}\Xi_c$	$1/2^-$	–
800	4022.66	0.00	$\bar{D}\Xi_c$	–	
600	4331.89	0.63	$\bar{D}^*\Xi_c$	$1/2^-$	$P_{cs}(4338)$
700	4255.98	0.21	$\bar{D}^*\Xi_c$	$1/2^-$	–
800	4154.76	0.08	$\bar{D}^*\Xi_c$	$1/2^-$	–
600	4424.27	11.75	$\bar{D}\Xi_c'$	$1/2^-$	$P_{cs}(4459)$
700	4400.58	15.38	$\bar{D}\Xi_c'$	$1/2^-$	–
800	4359.59	16.61	$\bar{D}\Xi_c'$	$1/2^-$	–
600	4565.96	31.73	$\bar{D}^*\Xi_c'$	$1/2^-$	–
700	4542.46	48.20	$\bar{D}^*\Xi_c'$	$1/2^-$	–
800	4500.58	49.56	$\bar{D}^*\Xi_c'$	$1/2^-$	–
600	4635.46	42.75	$\bar{D}^*\Xi_c^*$	$1/2^-$	–
700	4612.43	68.66	$\bar{D}^*\Xi_c^*$	$1/2^-$	–
800	4578.71	93.02	$\bar{D}^*\Xi_c^*$	$1/2^-$	–

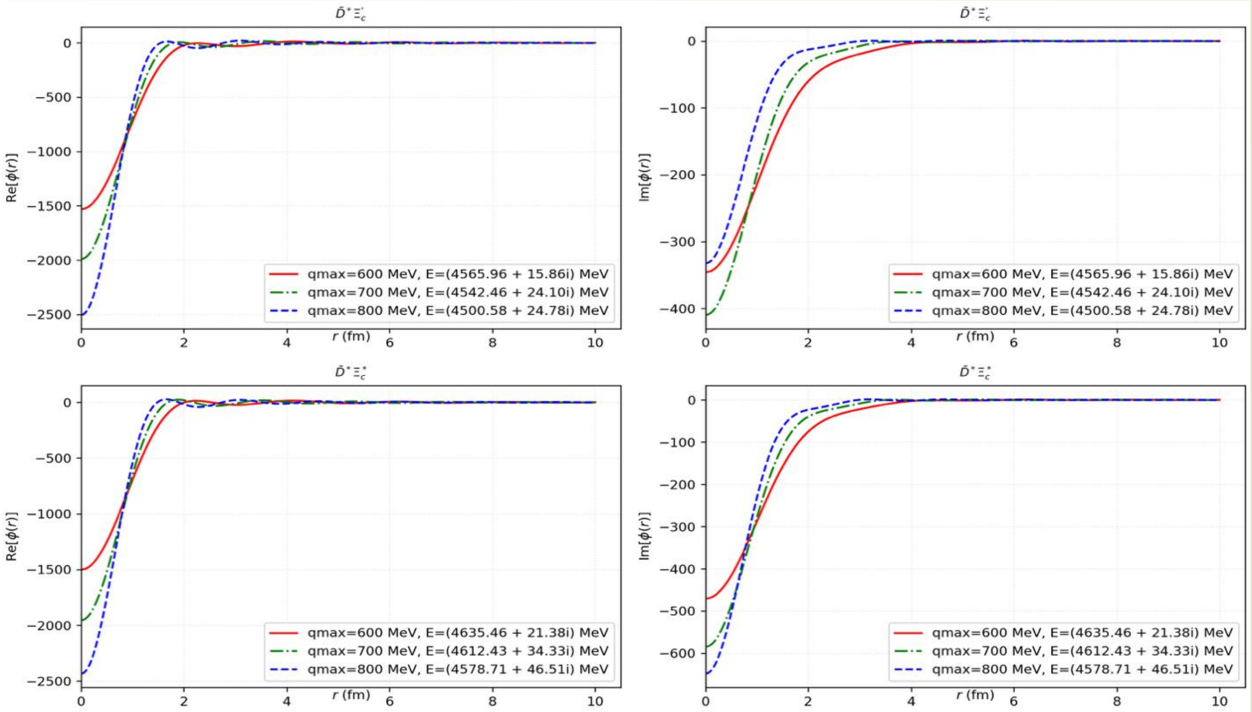
Pcs poles : PB and VB sectors



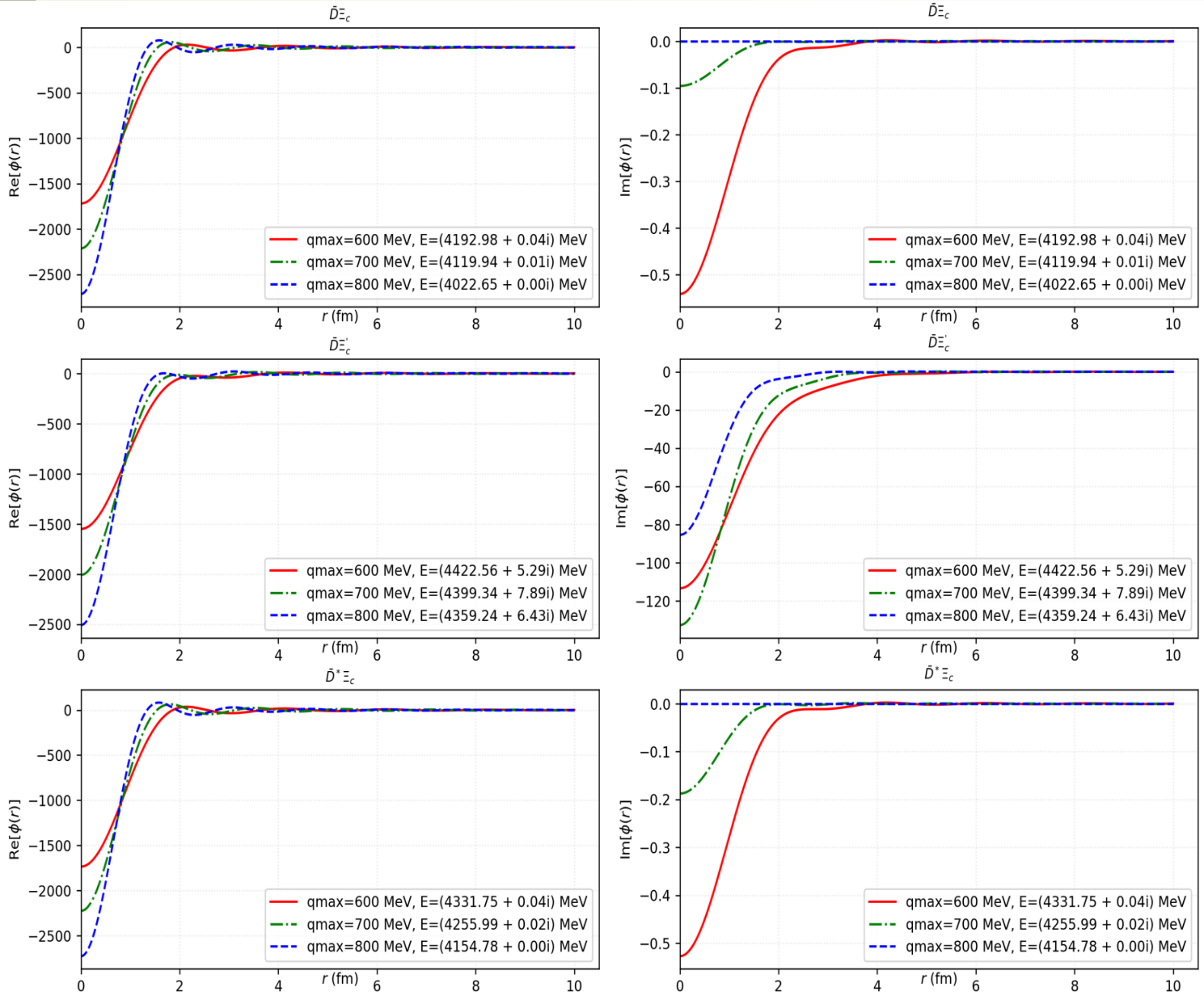
q_{max} [MeV]	Mass [MeV]	Width [MeV]	Main channel	Sector	J^P	Experimental state
600	4192.98	0.08	$\bar{D}\Xi_c$	PB	$1/2^-$	–
700	4119.94	0.02	$\bar{D}\Xi_c$	PB	$1/2^-$	–
800	4022.65	0.00	$\bar{D}\Xi_c$	PB	$1/2^-$	–
600	4331.75	0.08	$\bar{D}^*\Xi_c$	VB	$1/2^-$	$P_{cs}(4338)$
700	4255.99	0.03	$\bar{D}^*\Xi_c$	VB	$1/2^-$	–
800	4154.78	0.00	$\bar{D}^*\Xi_c$	VB	$1/2^-$	–
600	4422.56	10.58	$\bar{D}\Xi'_c$	PB	$1/2^-$	$P_{cs}(4459)$
700	4399.34	15.79	$\bar{D}\Xi'_c$	PB	$1/2^-$	–
800	4359.24	12.85	$\bar{D}\Xi'_c$	PB	$1/2^-$	–
600	4564.95	31.49	$\bar{D}^*\Xi'_c$	VB	$1/2^-$	–
700	4543.50	47.12	$\bar{D}^*\Xi'_c$	VB	$1/2^-$	–
800	4500.82	41.50	$\bar{D}^*\Xi'_c$	VB	$1/2^-$	–
600	4626.34	10.12	$\bar{D}^*\Xi^*_c$	VB	$1/2^-$	–
700	4598.59	17.05	$\bar{D}^*\Xi^*_c$	VB	$1/2^-$	–
800	4564.59	20.87	$\bar{D}^*\Xi^*_c$	VB	$1/2^-$	–

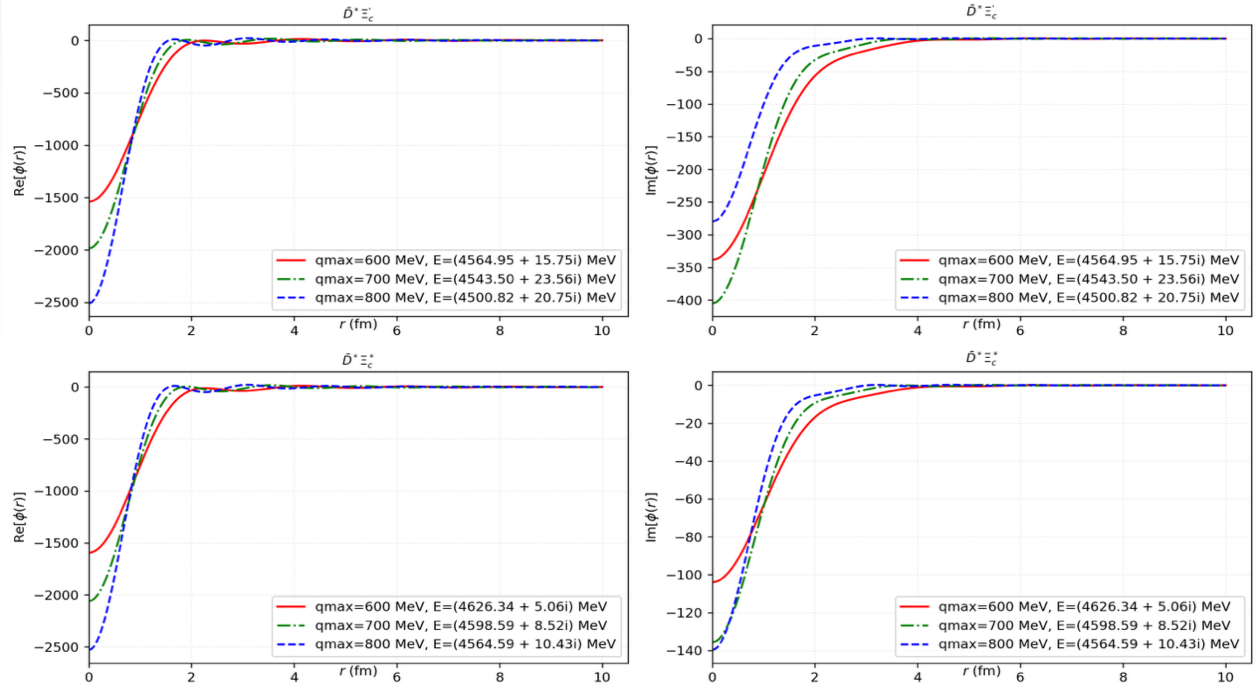
(2) Pcs wave functions : full coupled channels



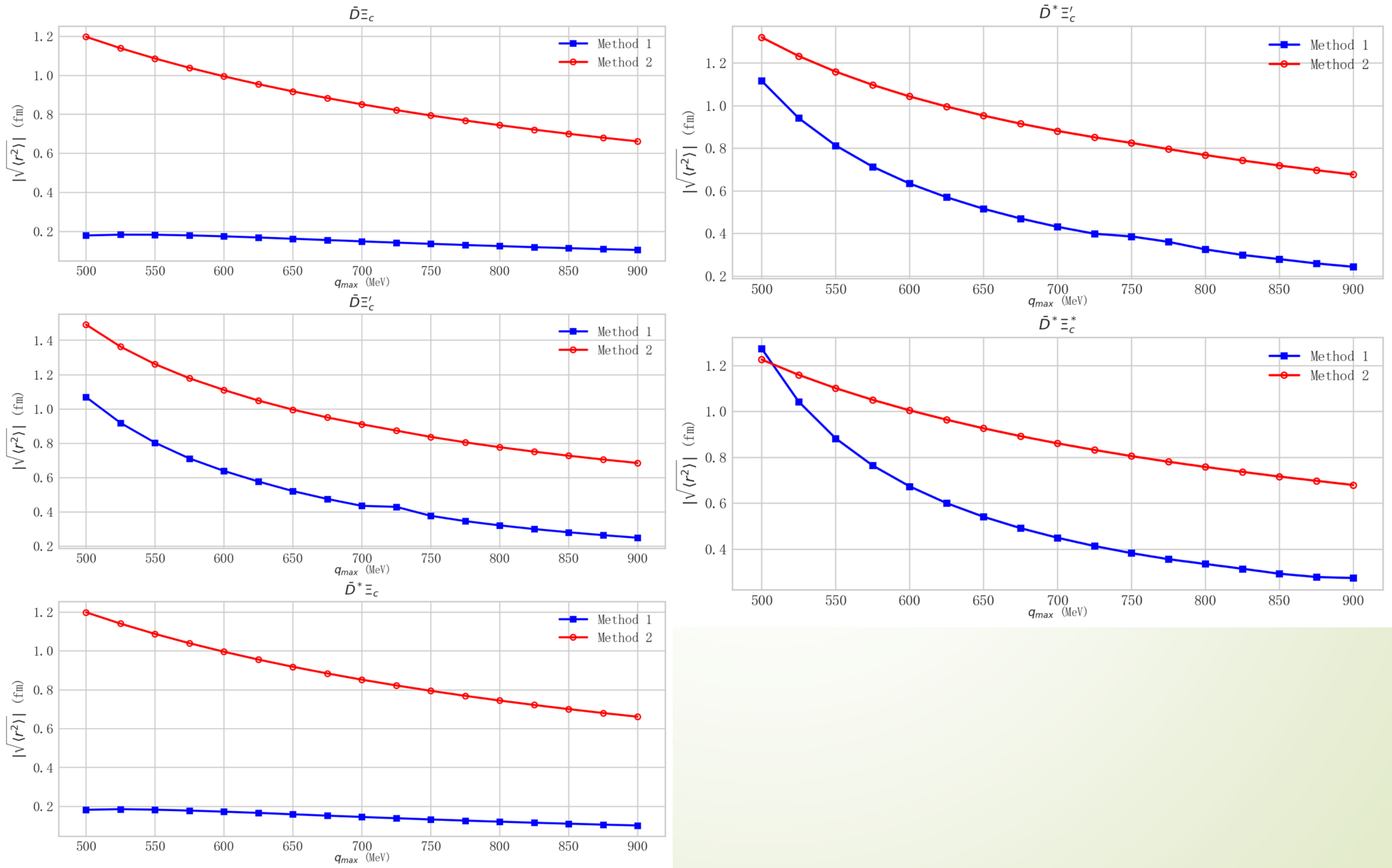


Pcs wave functions : PB and VB sectors

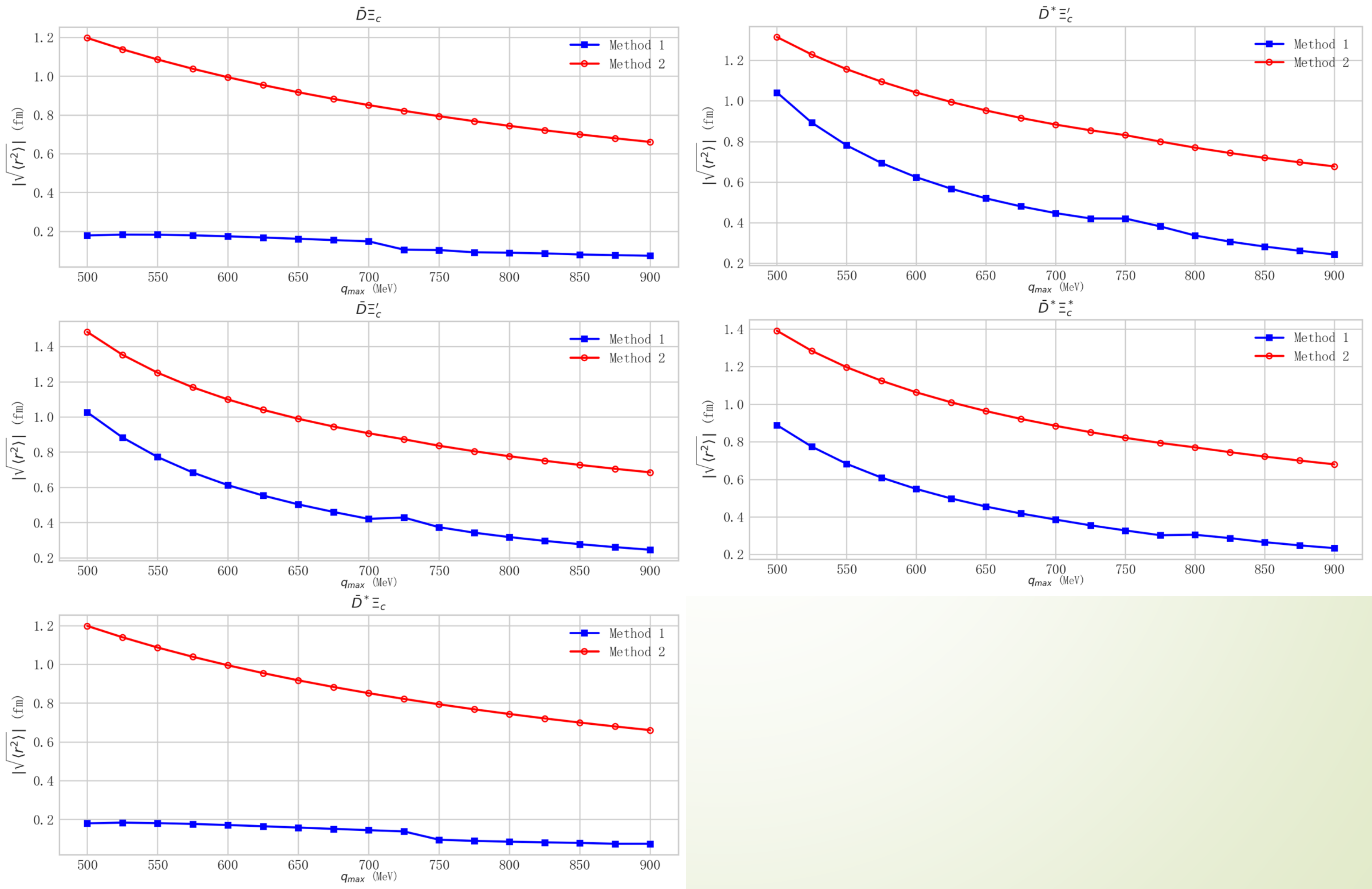




(3) Pcs radii: full coupled channels

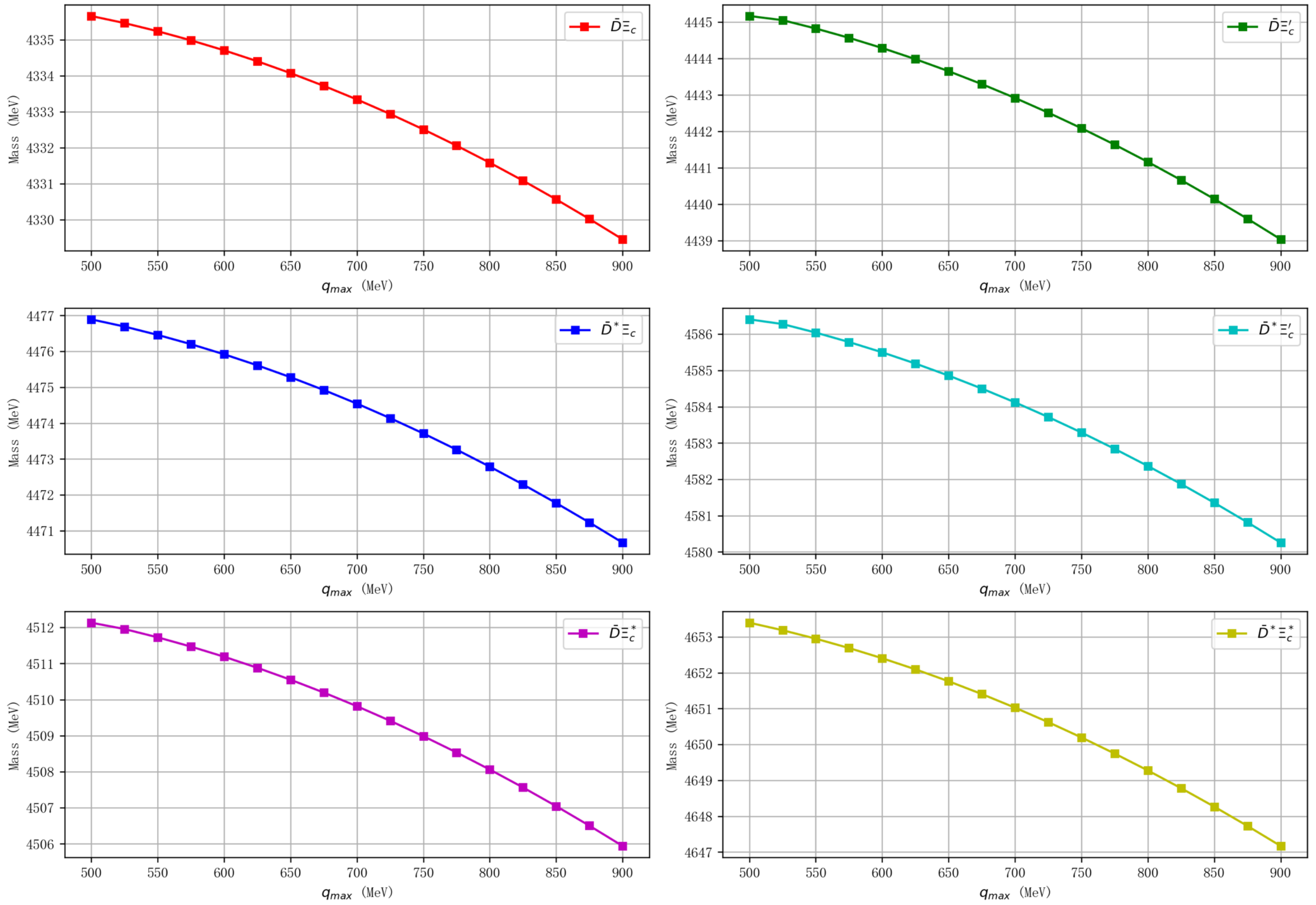


(3) Pcs radii: PB and VB sectors

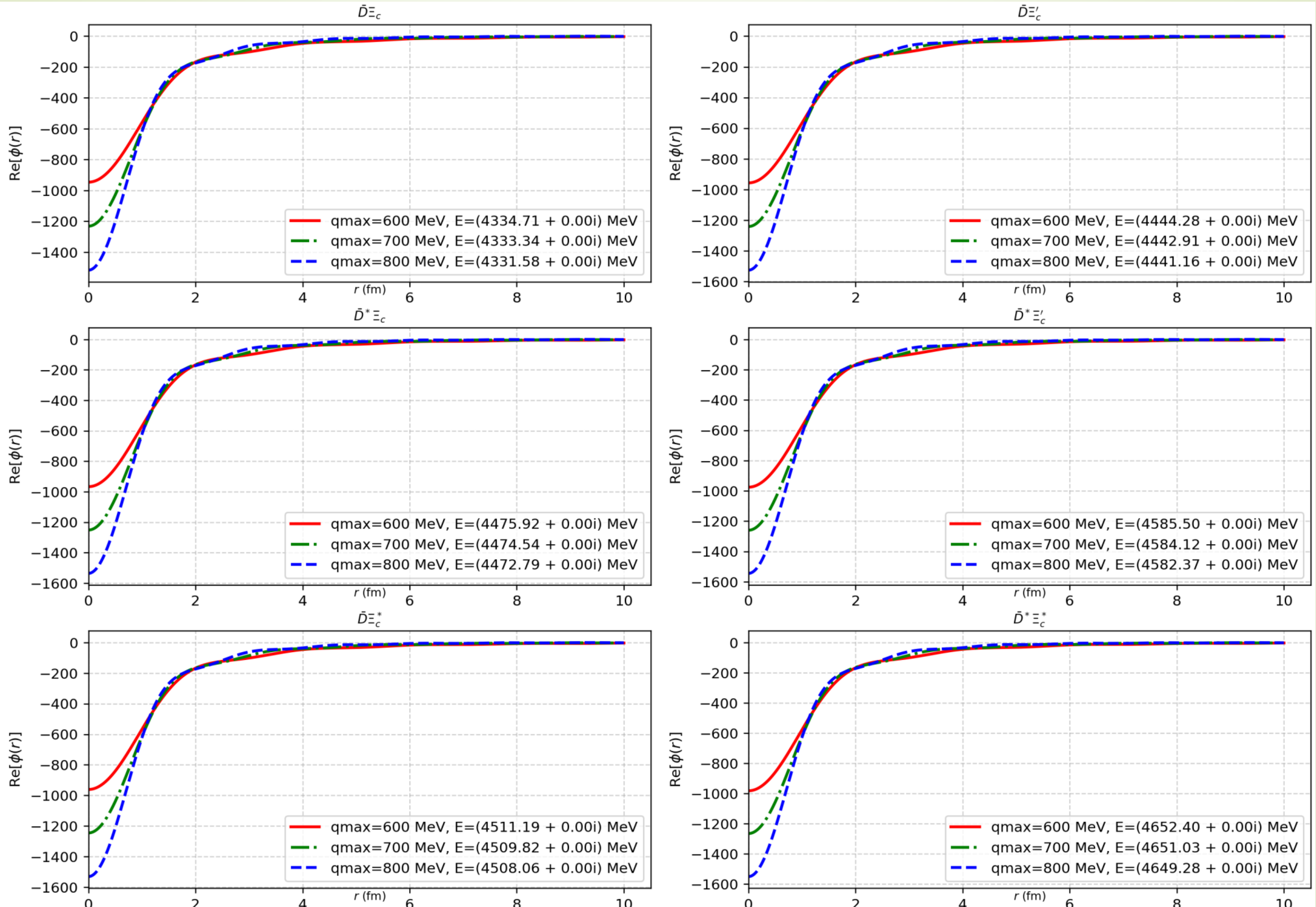


(4) Single channel interaction poles:

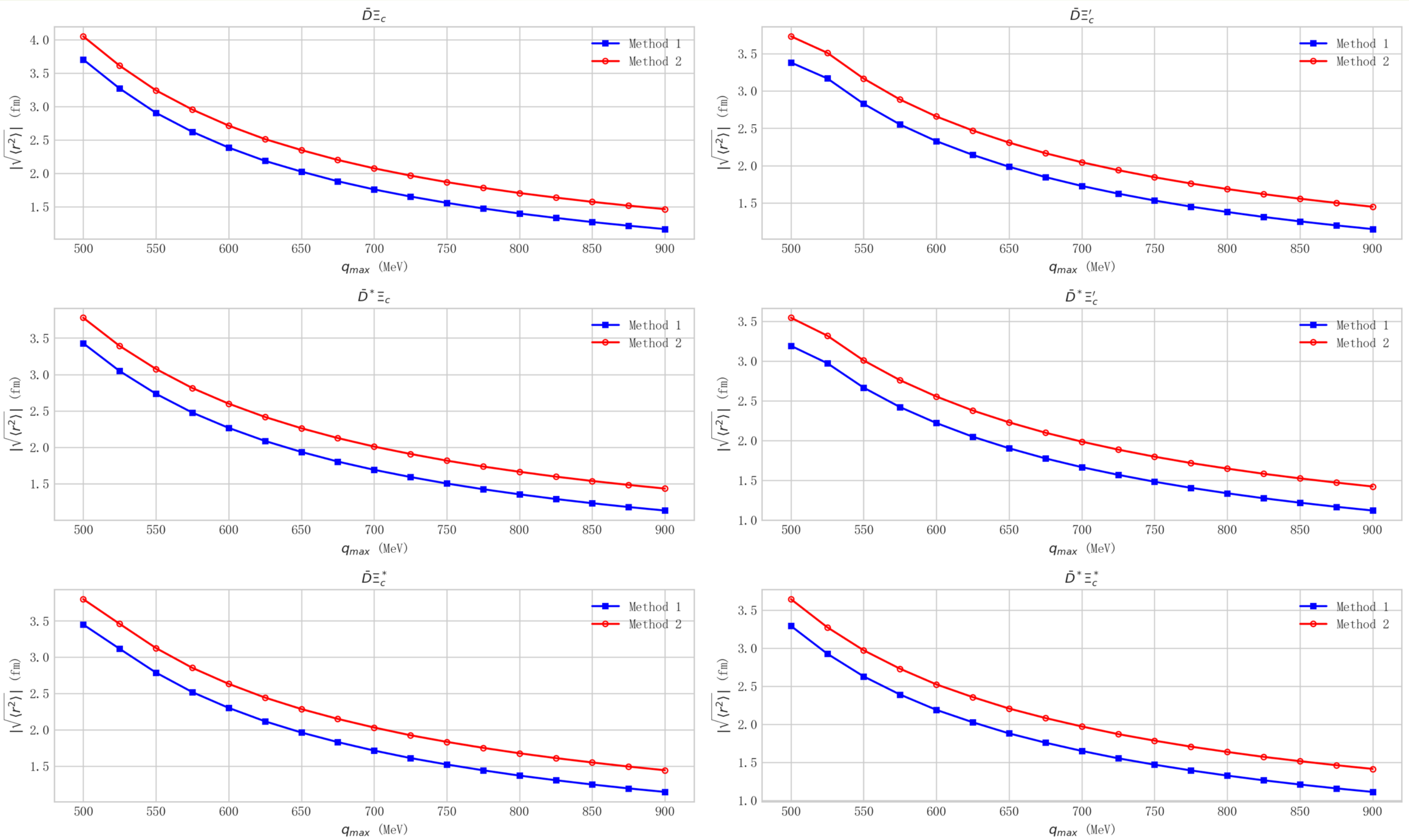
$J^P = 3/2^-$ **Pcs states**



Wave functions:



Radii:



$\bar{D}\Xi_c$
$\bar{D}\Xi_c'$
$\bar{D}^*\Xi_c$
$\bar{D}^*\Xi_c'$
$\bar{D}\Xi_c^*$
$\bar{D}^*\Xi_c^*$
Method 1
Method 2
$|\sqrt{\langle r^2\rangle}|$ (fm)
q_{max} (MeV)
500
550
600
650
700
750
800
850
900
1.0
1.5
2.0
2.5
3.0
3.5
4.0

§4. Summary

- To generate the Pc states, the full coupled channel interactions with the heavy quark spin symmetry are important, which affect seriously the widths of the corresponding poles.
- it is not so necessary to reproduce the Pcs state using the full coupled channel interactions with the heavy quark spin symmetry, showing that the results of the splitting PB and VB sectors are not much differences.
- all the main bound channels have similar binding energies for the single channel interactions.

Thanks for your attention!

感谢大家的聆听！