Recent Results on Isospin-Violating Transitions in Charmonium Studied with BESIII

Olga Bondarenko (KVI, University of Groningen)
on behalf of the BESIII collaboration

Collaboration meeting June 2012 @ Suzhou

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Outline:

- Coupled-channels effects
- Isospin-violating transitions
- Precision measurements @ BESIII

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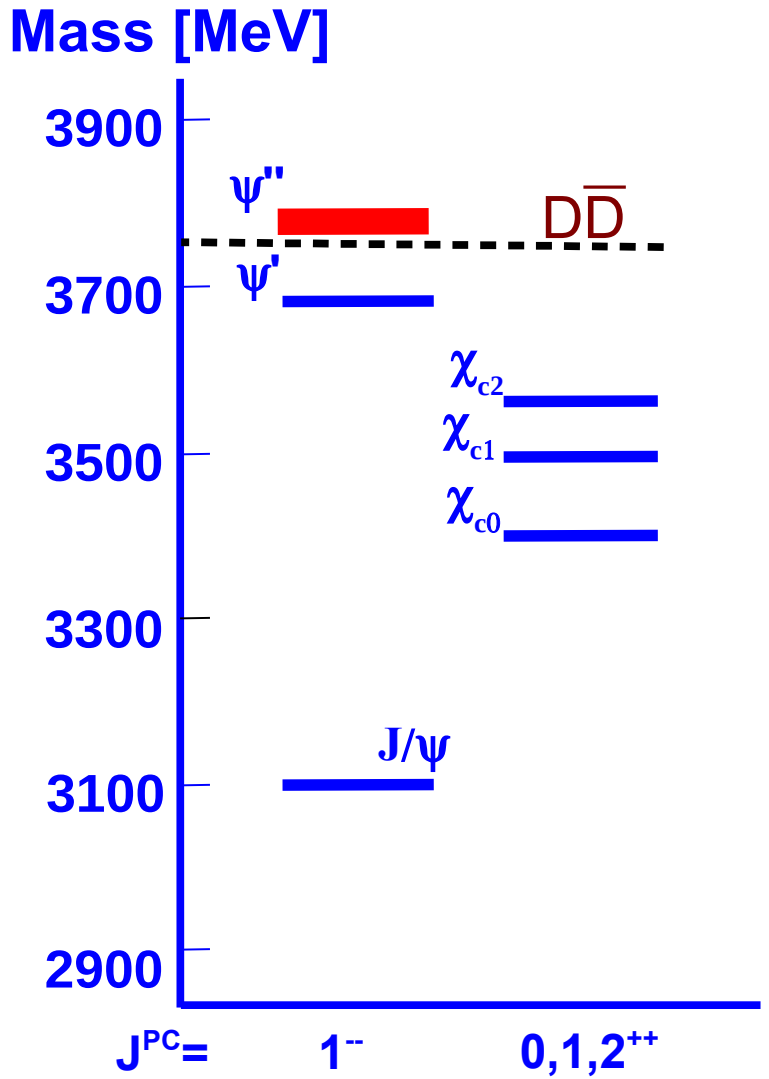
Charmonium above the Open-Charm Threshold



Experiment:
M(ψ'') = 3773.2±0.3 MeV

PDG2012

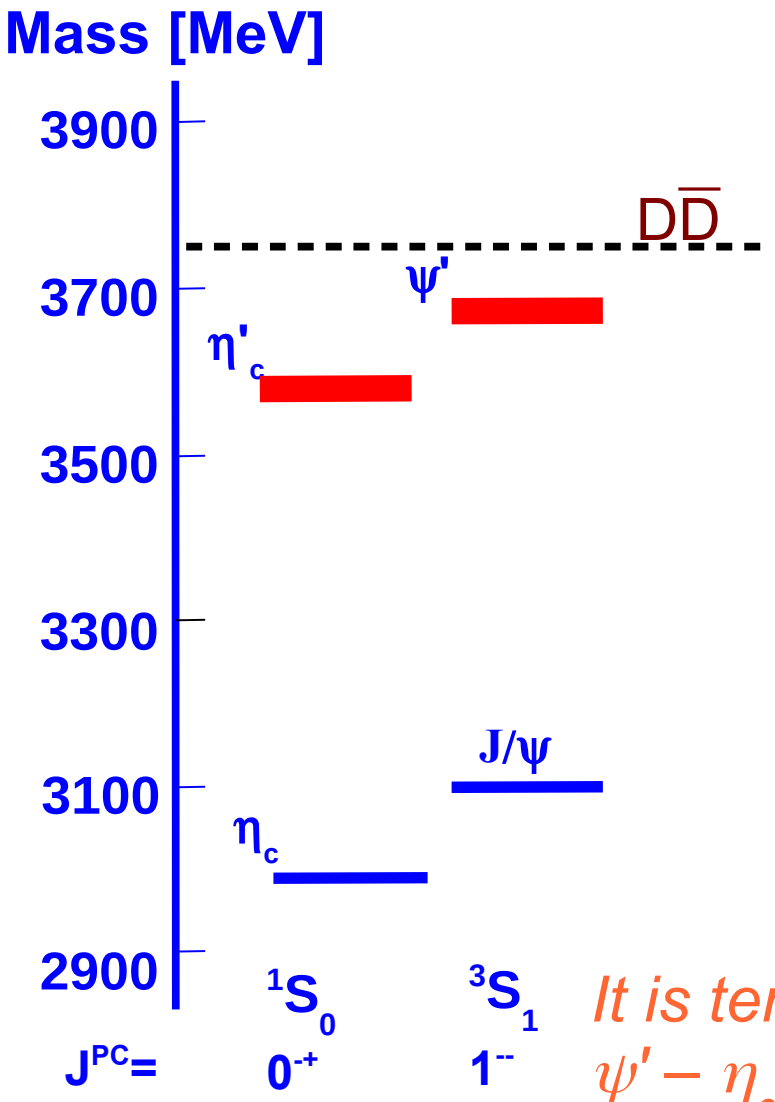
Potential (Coulomb+linear) Model
M(ψ'') = 3810 MeV

Coupled-Channels Model
M(ψ'') = 3755 MeV

Eichten et al., PRD 21, 203 (1980)

Influence of virtual decay channels is significant above the open charm threshold

2S Hyperfine Splitting



Experiment:

$M(\psi') - M(\eta_c') = 48.5 \pm 3.3$ MeV

BESIII, PRL 109, 042003(2012)

Potential (Coulomb+linear) Model

$M(\psi') - M(\eta_c') = 67$ MeV

Coupled-Channels Model

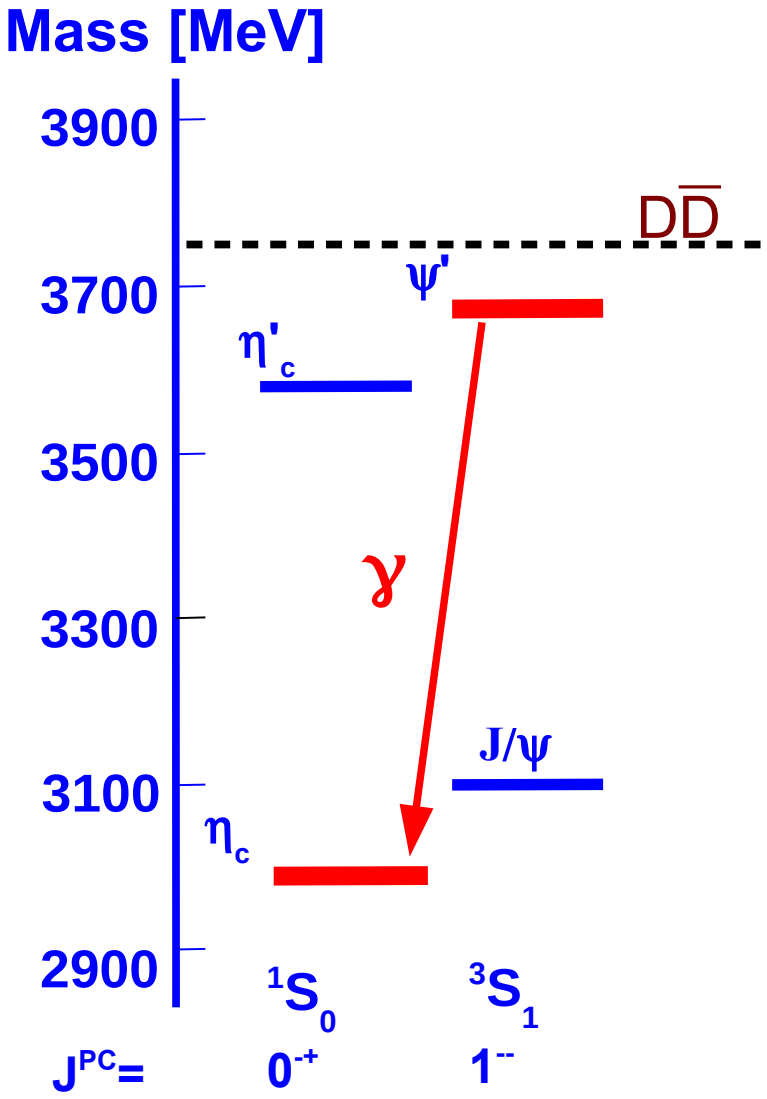
$M(\psi') - M(\eta_c') = 46$ MeV

Eichten et al., PRD 69, 094019 (2004)

It is tempting to conclude that the $\psi' - \eta_c'$ splitting reflects the influence of virtual decay channels.

E.Eichten at al., PRD 69, 094019 (2004)

M1 Radiative Transition



Experiment:

$\Gamma(\psi' \to \gamma\eta_c) = 0.97 \pm 0.14$ keV

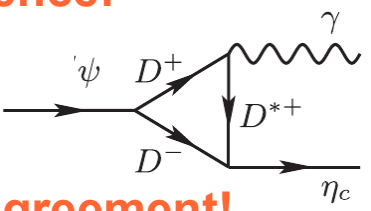
CLEOc, PRL 102, 011801 (2009)

Non-relativistic Potential Model

$\Gamma(\psi' \to \gamma\eta_c) = 9.7$ keV ←One order of magnitude difference!

+ Intermediate Meson Loops

$\Gamma(\psi' \to \gamma\eta_c) = 2.05^{+2.65}_{-1.75}$ keV ←Agreement!



G.Li and Q.Zhao, PRD 84, 074005 (2011)

Lattice

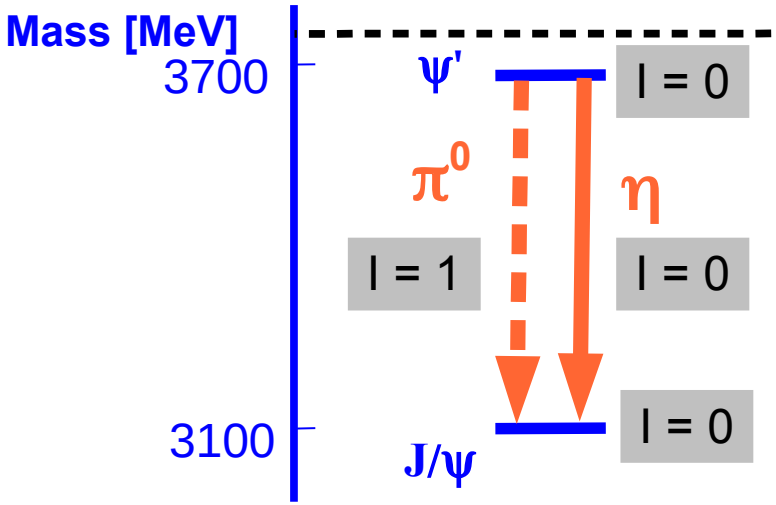
$\Gamma(\psi' \to \gamma\eta_c) = 0.4 \pm 0.8$ keV

J.Dudek et al., PRD 73, 094504 (2009)

Influence of virtual decay channels seems to be significant

Isospin violating transitions

Sources of symmetry breaking:
- the up-down quark mass difference
- electromagnetic interaction



J.F. Donoghue (1989), K. Maltman (1991):
EM contribution for $\psi' \to \pi^0 J/\psi$ is much smaller than the quark-mass difference.

➔ Effective Field Theory
(0th order QCD multipole expansion)

$$\frac{B(\Psi' \to \pi^0 J/\psi)}{B(\Psi' \to \eta J/\psi)} \Leftrightarrow \frac{m_u}{m_d} = 0.40 \pm 0.01$$

Result contradicts previous estimates from light-meson mass ratio:

$$\frac{m_u}{m_d} = \frac{M_K^2 - M_{K_0}^2 + 2M_{\pi^0}^2 - M_\pi^2}{M_{K^0}^2 - M_K^2 + M_\pi^2} = 0.56$$

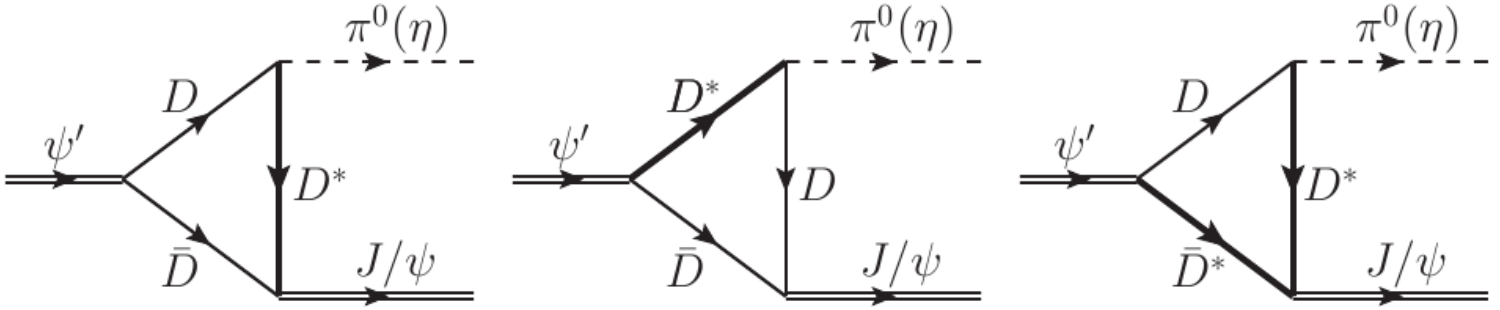
Weinberg (1977); Gasser, Leutwyler (1982); Leutwyler (1996)

Isospin violating transitions: Charmed-meson loops

➔ EFT
(1st order QCD multipole expansion)

$$\frac{m_u}{m_d} \Leftrightarrow R = \frac{B(\psi' \to \pi^0 J/\psi)}{B(\psi' \to \eta J/\psi)} + loops\ !$$

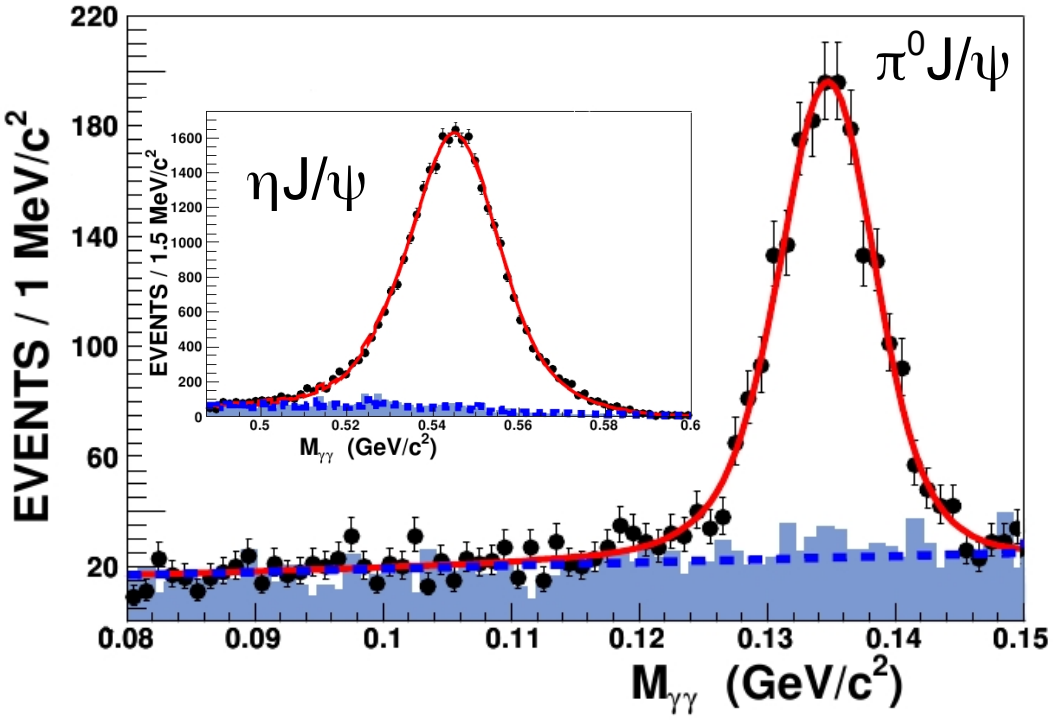
F.-K. Guo: PRL 103, 082003 (2009)



Are these charmed-meson loops important?

We are interested in π^0(~~isospin~~) transitions between various charmonium states in order to reveal the hadronic-loop contributions to light quark masses (communication with Juelich+IHEP theory groups).

Isospin violating $\psi' \to \pi^0 J/\psi$ @BESIII



Low background!
A clean probe!

$$\frac{B(\psi' \to \pi^0 J/\psi)}{B(\psi' \to \eta J/\psi)}(\%)$$

CLEO-c	$3.88 \pm 0.23 \pm 0.05$
EFT	$11 \pm \mathbf{6}$ (*)
BESIII	**$3.74 \pm 0.06 \pm 0.04$**

PRD 78, 011102 (2008)

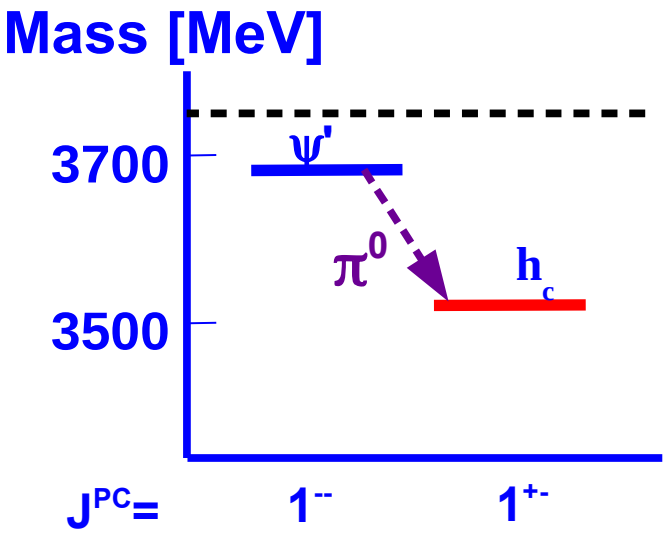
(*) F.-K. Guo, PRL. 104, 109901(E) (2010)

PRD 86, 092008 (2012)

Best Measurement!

Can constrain EFT!

Isospin violating $\psi' \to \pi^0 h_c$ @BESIII



$$B(\psi' \to \pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0)\cdot 10^{-4}$$

PRL 104, 132002 (2010)

Tiny branching fraction! First Measurement!

Theory, NREFT: charmed-meson loops contribution is about 10%.
Tree-level diagram + dimensional analysis:

$$\Gamma(\psi' \to \pi^0 h_c) = (0.9 \pm 0.6) C^2 \text{ keV}, \; C \approx 1$$

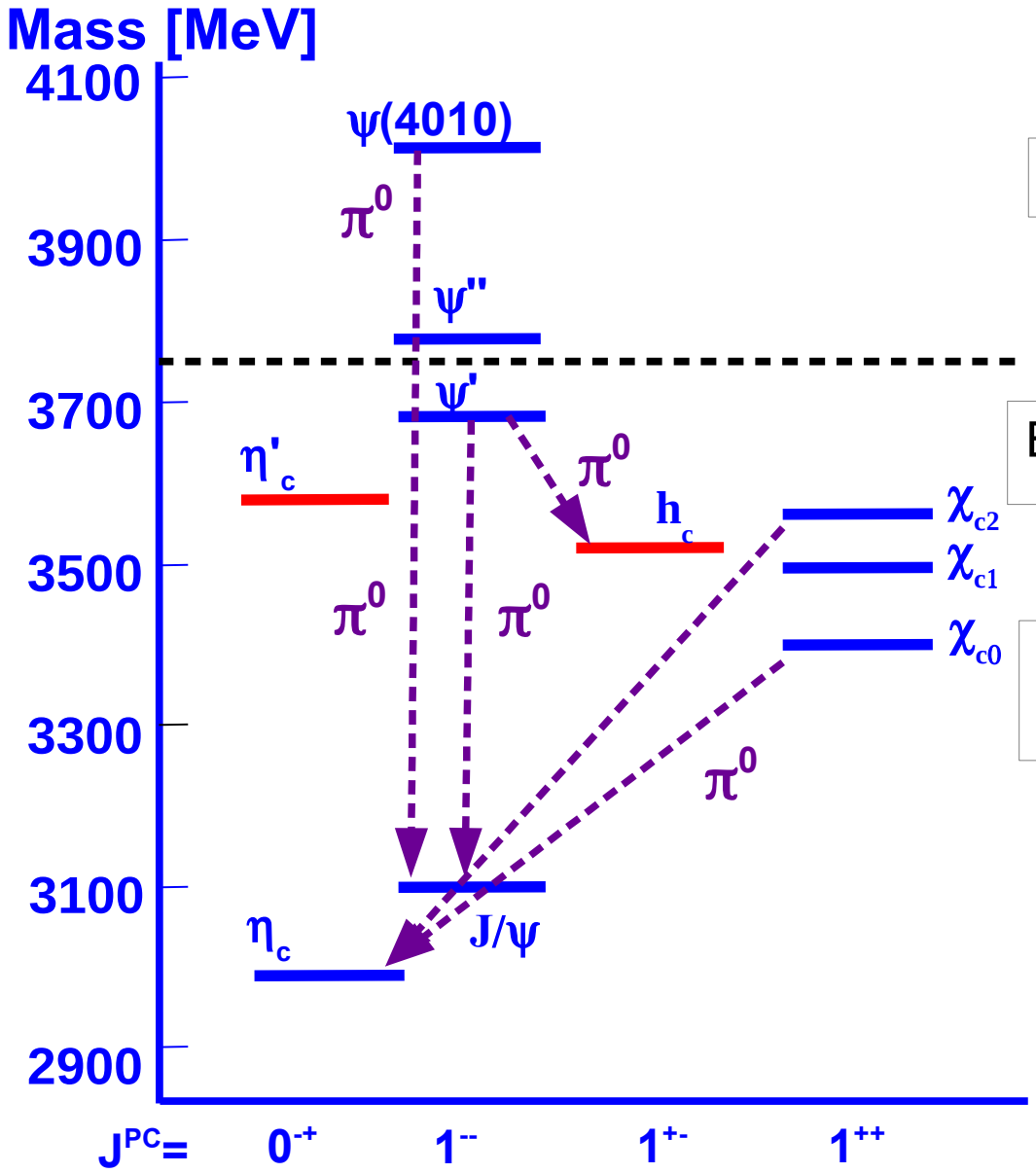
F.-K. Guo, PRD 82, 034025 (2010)

$$\Gamma(\psi' \to \pi^0 h_c) = (0.26 \pm 0.05) \text{ keV}$$

BESIII

Results are in agreement,
the NREFT approach is promising

Isospin violating transitions @ BESIII



$B(\psi(4010) \to \pi^0 J/\psi) < 2.8 \cdot 10^{-4}$

Phys. Rev. D 86, 071101(R) (2012)

$B(\psi' \to \pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0) \cdot 10^{-4}$

PRL 104, 132002 (2010)

$B(\psi' \to \pi^0 J/\psi)/B(\psi' \to \eta J/\psi) = (3.74 \pm 0.06 \pm 0.04) \cdot 10^{-2}$

PRD 86, 092008 (2012)

$B(\chi_{c0,2} \to \pi^0 \eta_c) < ?$

In Progress

A lot of new results!
Systematic studies are on-going!

Summary

- Effects of intermediate charmed-meson loops on charmonium transitions below the open charm threshold are subject of extensive experimental and theoretical studies.
- Systematic studies of isospin-violating transitions are performed @ BESIII.
- These studies will help to constrain existing theoretical models.
- A good control of intermediate charmed-meson loops will help to access fundamental paremeters, e.g. light-quark masses.
- Studies are on-going and a lot of new results are expected in the near future.