The line shape of Y(4260)

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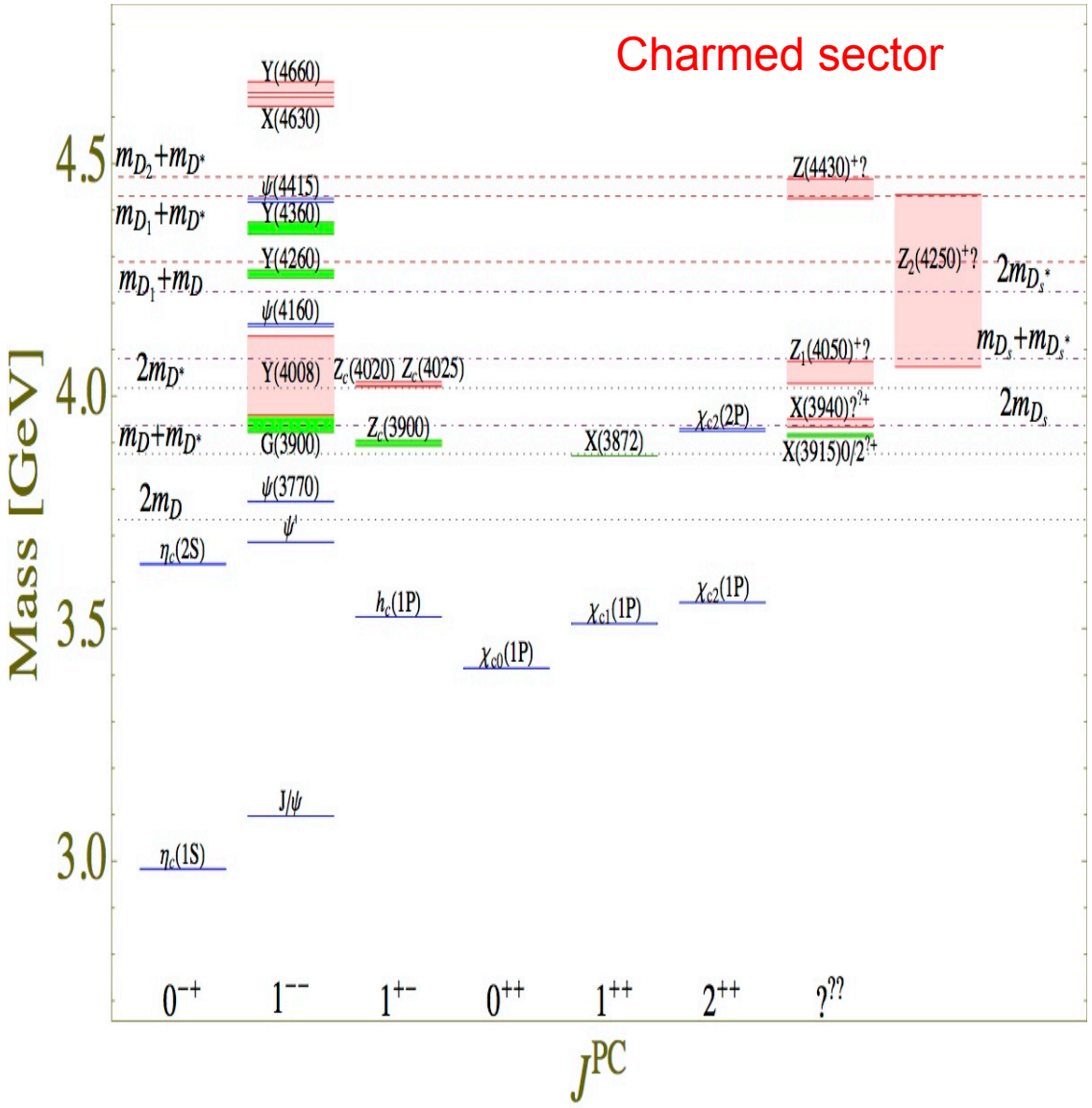
CERN, 11th November 2014

JÜLICH
FORSCHUNGSZENTRUM

Outline

- Motivation
- The molecular implications of Y(4260)
  - Some facts of Y(4260)
  - The line shape of Y(4260)
- Summary and outlook

The observation of "X, Y, Z" states

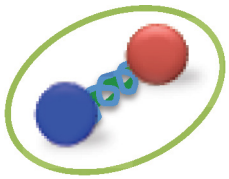


- Mass positions close to open-flavor thresholds
- Charged states with hidden charm or bottom
- Cannot be accommodated by conventional quark model

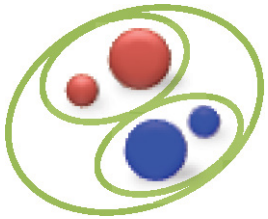
What is their nature?

Motivation

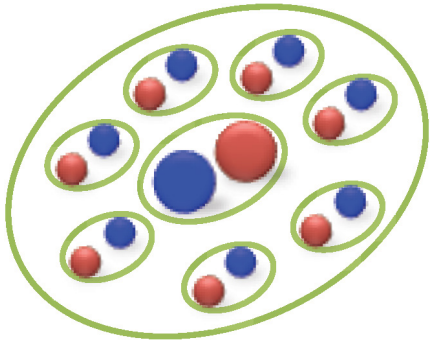
QCD allows for various color neutral states besides "conventional mesons"



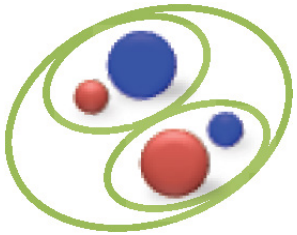
Hybrid



Tetraquark



Hadrocharmonium



Molecule

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Motivation

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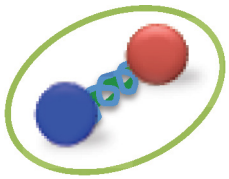

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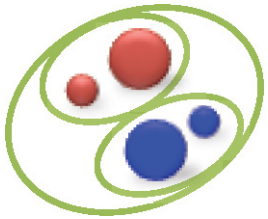

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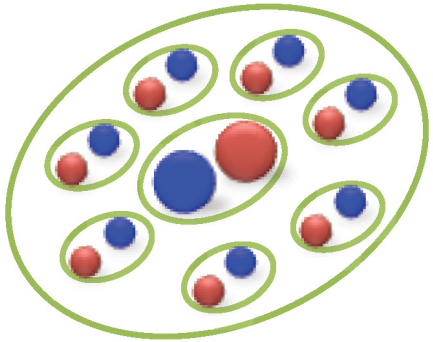

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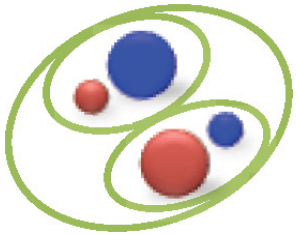

Molecule

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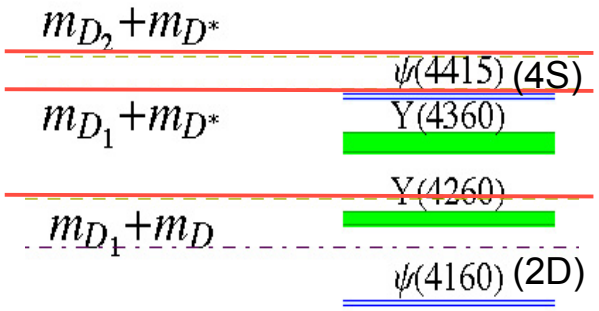
The nature of Y(4260)?

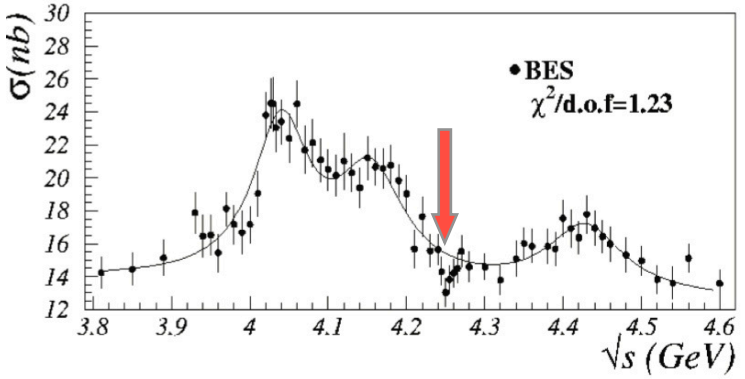
Some facts of Y(4260)

- A few tens MeV below D_1D threshold

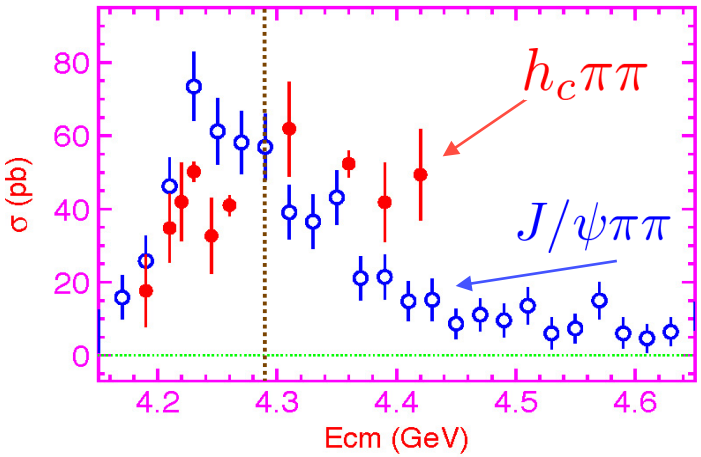


PDG 2014

- Absence in e^+e^- inclusive process

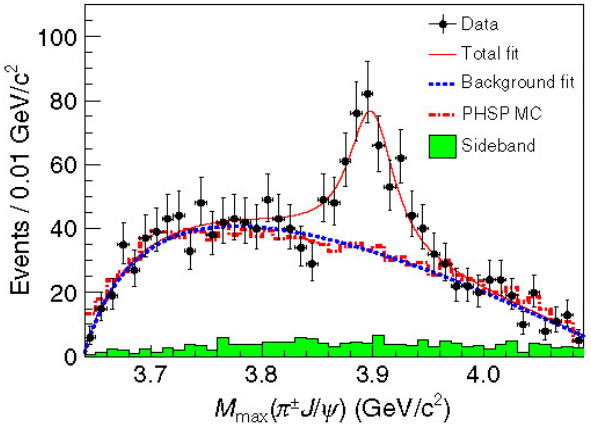


- Observed in $J/\psi\pi\pi$channel



Belle, PRL99, 182004 (2007), BESIII, PRL111, 242001 (2013)

- The observation of $Z_c(3900)$ in $J/\psi\pi$ invariant mass in Y(4260)-> $J/\psi\pi\pi$

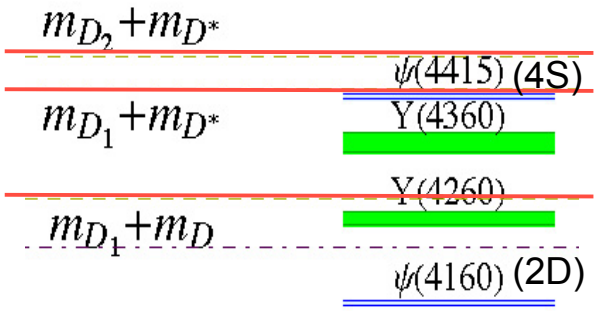


BESIII,PRL 110, 252001,Belle,PRL 110, 252001,CLEO,PLB 727, 366

The molecular implications of Y(4260)

Some facts of Y(4260)

- A few tens MeV below D_1D threshold



PDG 2014

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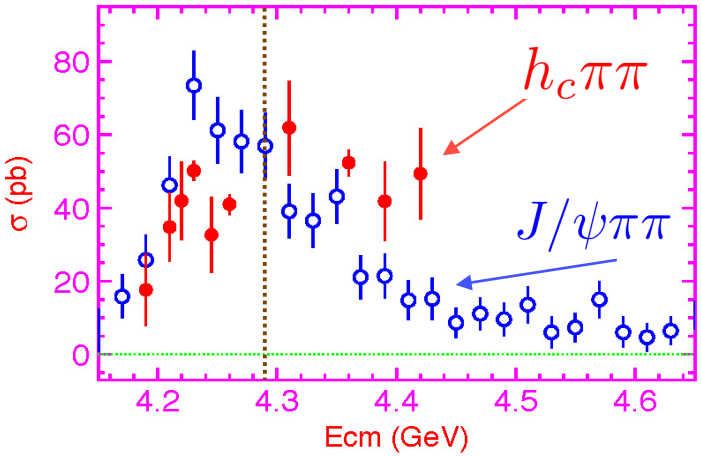
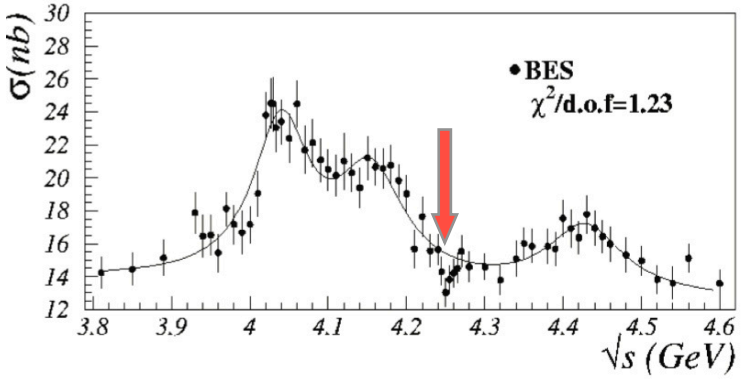


Belle, PRL99, 182004 (2007), BESIII, PRL111, 242001 (2013)

The D_1D molecular picture can explain all these phenomena!

- Absence in e^+e^- inclusive process



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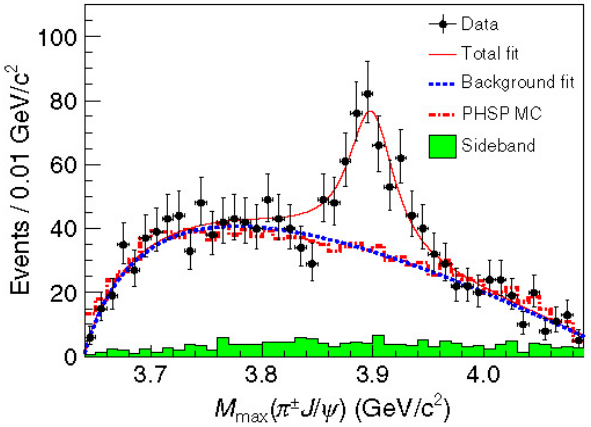
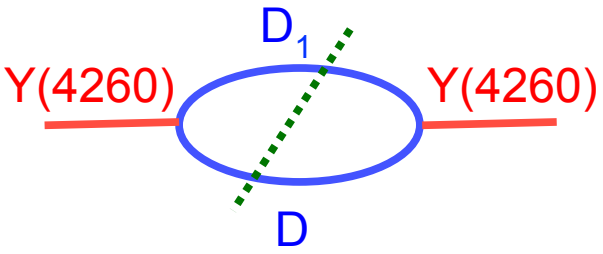


BESIII,PRL 110, 252001,Belle,PRL 110, 252001,CLEO,PLB 727, 366

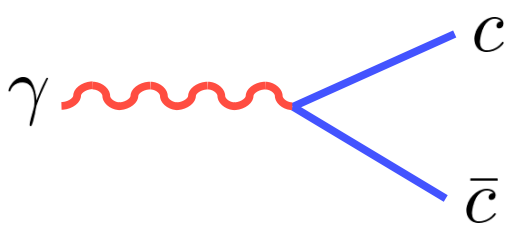
The molecular implications of Y(4260)

- The property of Y(4260) will be determined by the D_1D threshold



- Universal coupling
- Driven by D_1D threshold

- Absence in e^+e^- inclusive process



Suppressed

S-wave D-wave

$$\bar{u}(p)\gamma_i v(q) = \frac{E+m_c}{2m_c}\left((1+\frac{|\vec{p}|^2}{3(E+m_c)^2})\delta^{ij} - 2\frac{|\vec{p}|^2}{(E+m_c)^2}(n^i n^j - \frac{1}{3}\delta^{ij})\right)\chi^\dagger\sigma^j\eta$$

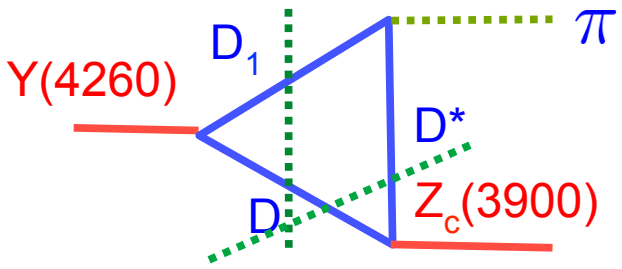
In the heavy quark symmetry: $\frac{1}{2}\otimes\frac{3}{2} = 1\oplus 2$

(D, D*) (D_1, D_2)

X. Li, M.B. Voloshin, PRD88, 034012(2013)

The molecular implications of Y(4260)

- The triangle singularity mechanism



- Rich production of DD* pair will create the $Z_c(3900)$
- The kinematics for $Y(4260)\to Z_c(3900)\pi$ through the meson loops satisfies the triangle singularity condition.

J.J. Wu, et al, PRL 108, 081803(2012), Q.W., C.Hanhart and Q.Zhao, PLB725,106(2013)

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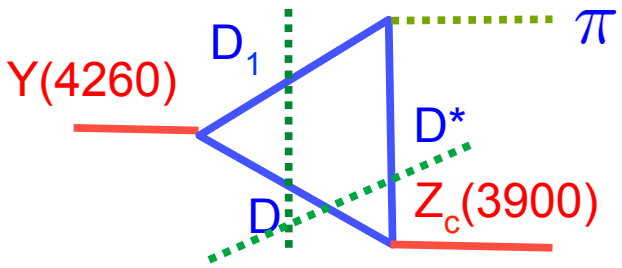

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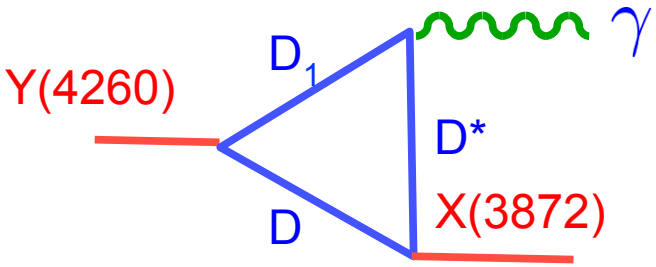


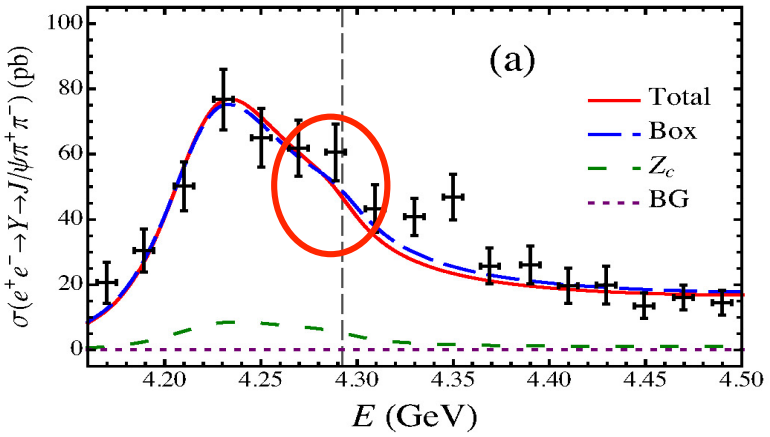
Similarities between these two processes allow to predict sizable branching fraction for Y(4260)-> X(3872) γ

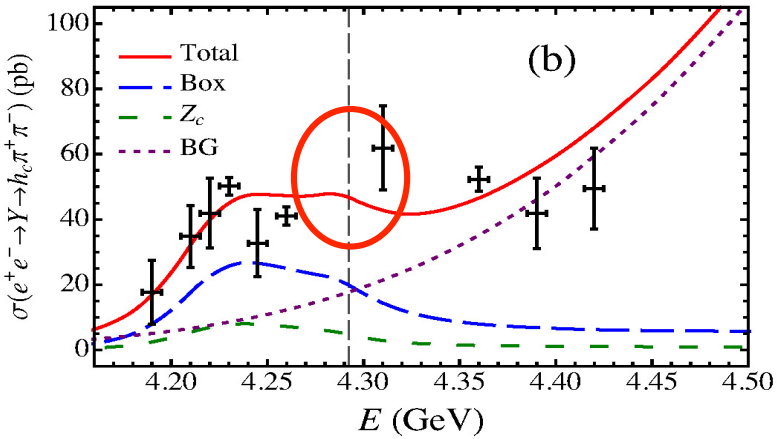
Confirmed by BESIII

F.G. Guo, et al, PLB 725,127 (2013), C.Z. Yuan, hep-ex/1310.0280 (2013)

The molecular implications of Y(4260)

The line shapes of Y(4260) in $J/\psi\pi\pi$ and $h_c\pi\pi$ channels





$$M_Y = 4217.2 \pm 2.0 \text{ MeV} \qquad \hat{\Gamma}_Y = 55.91 \pm 2.6 \text{ MeV}$$

- D_1D cusp effect
- Not symmetric Breit-Wigner distribution
- Lower pole mass

M. Cleven, et al., PRD90,074039 (2014), Belle, PRL99, 182004 (2007), BESIII, PRL111, 242001 (2013)

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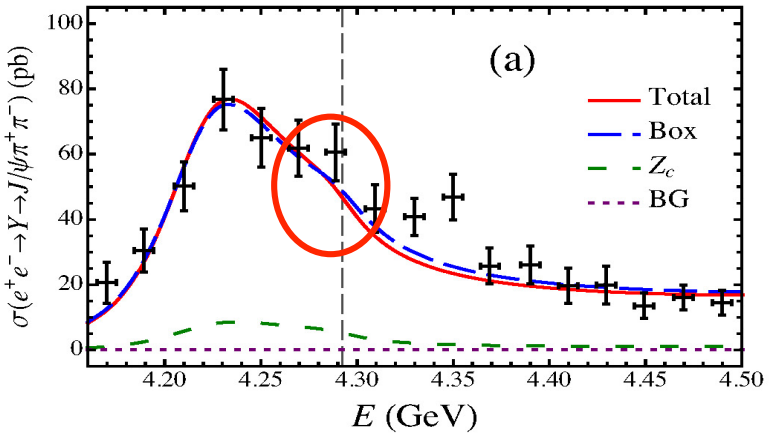

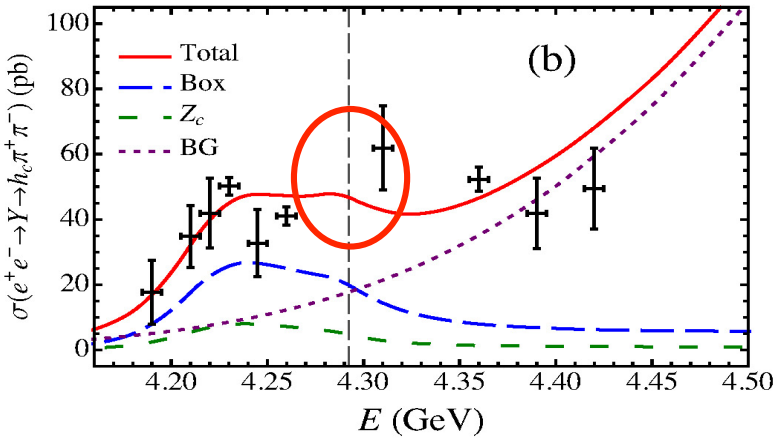

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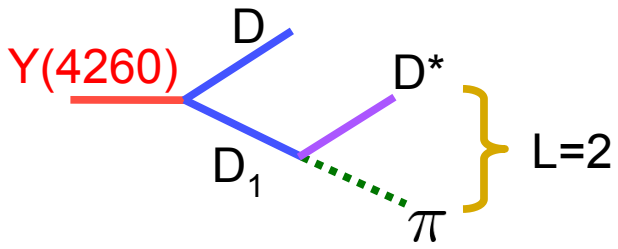
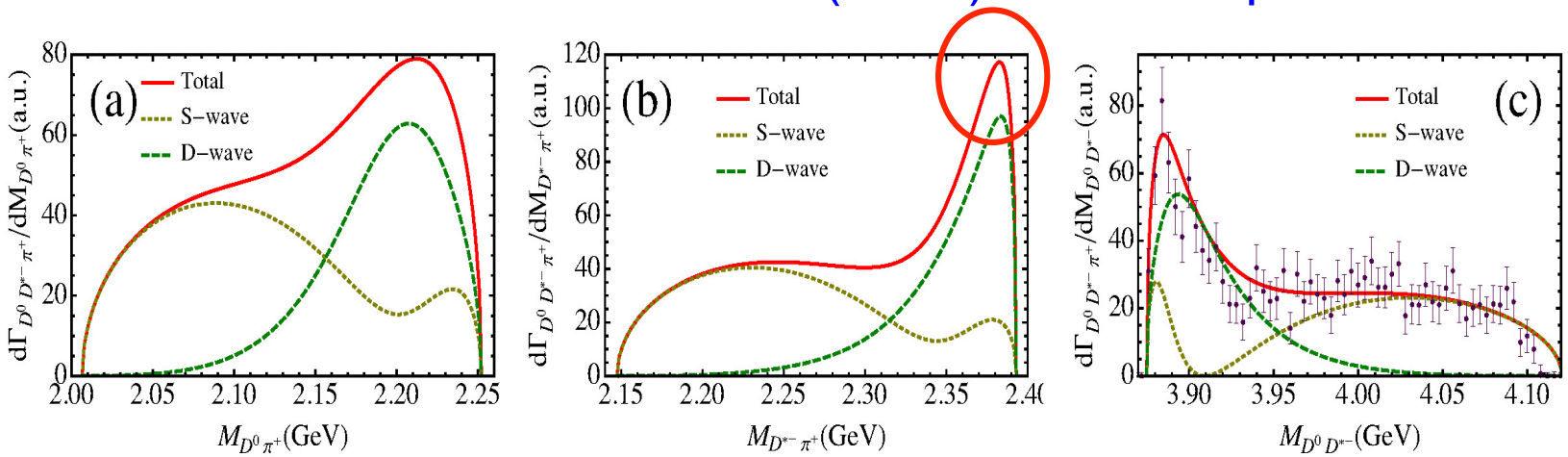


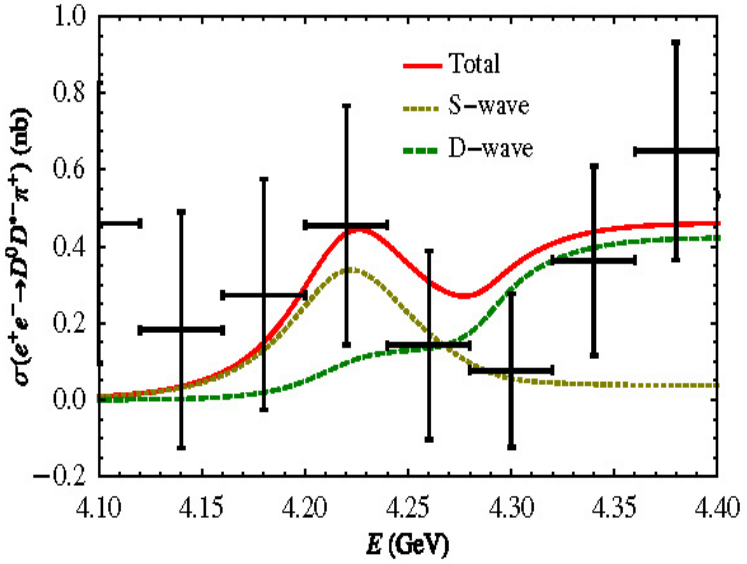
- Large partial width
- Presence of D wave pion

M. Cleven, et al., PRD90,074039 (2014), Belle, PRL99, 182004 (2007), BESIII, PRL111, 242001 (2013)

The molecular implications of Y(4260)

The invariant mass distributions in Y(4260) to DD* π process





- D_1 pole in D*pi invariant mass
- Pronounced peak in D*D invariant mass
- Highly non-trivial structure
- Not Breit-Wigner line shape
- Improved measurements necessary

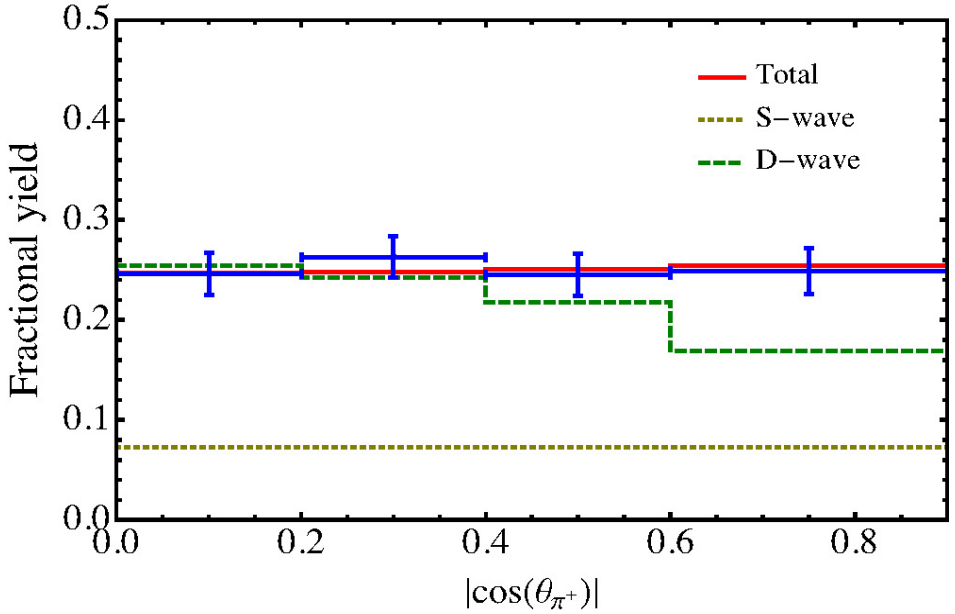
M. Cleven, et al., PRD90,074039 (2014), Belle, PRL99, 182004 (2007), BESIII, PRL111, 242001 (2013)

The molecular implications of Y(4260)

Jackson angular distribution in Y(4260) to DD*pi process:

$$\mathcal{M} = \epsilon_Y^a \epsilon_{Z_c}^b \left(C_S \delta^{ab} + C_D \left(\hat{q}^a \hat{q}^b - \frac{1}{3}\delta^{ab} \right) \right)$$

$$\sum_{\text{polarizations}} |\mathcal{M}|^2 = 2C_S^2 - 2C_S C_D \cos^2\theta_\pi + \frac{2C_S C_D}{3} - \frac{C_D^2 \cos^2\theta_\pi}{3} + \frac{5C_D^2}{9}$$



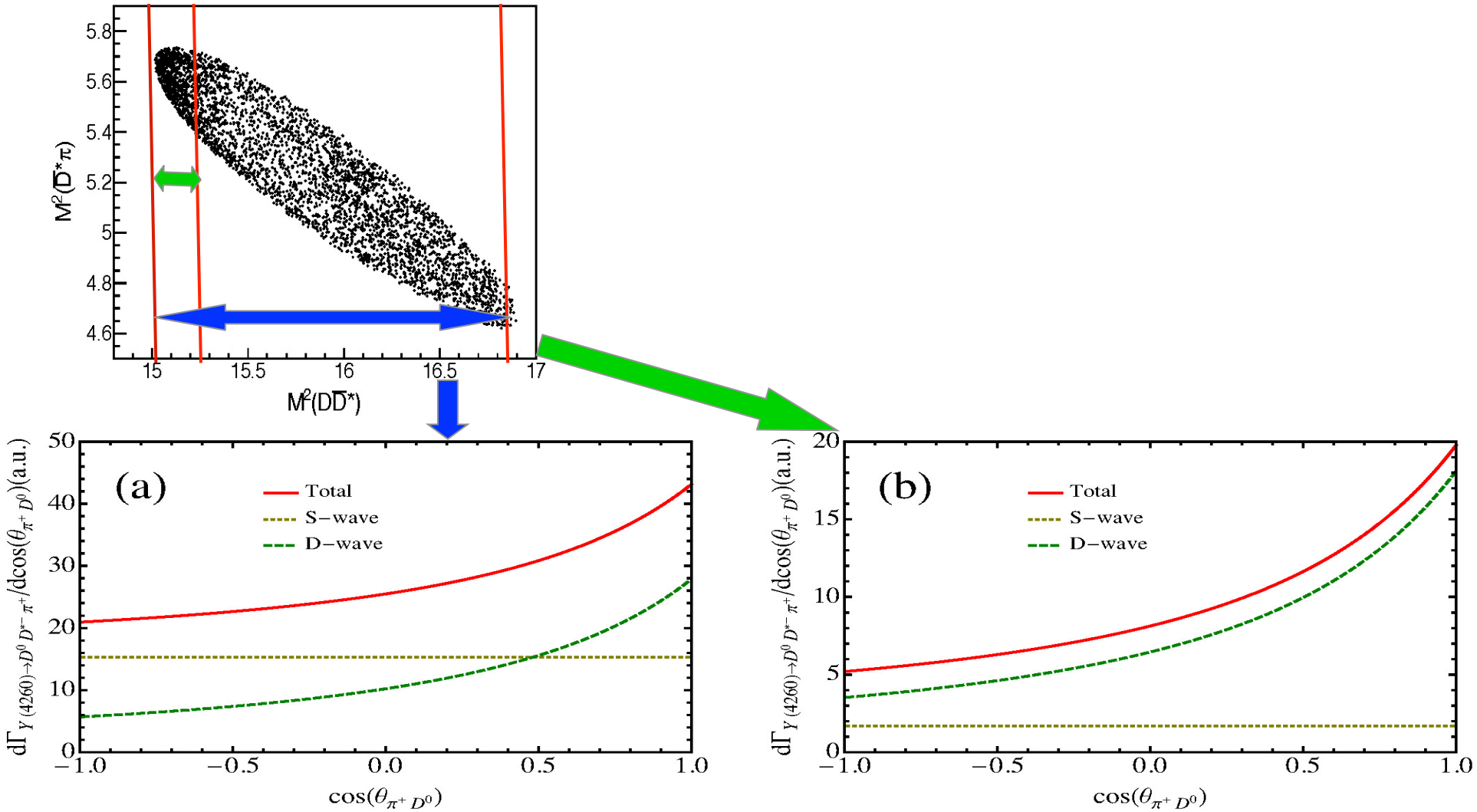
two solutions

- One is only S-wave
- One is D-wave dominance

M. Cleven, et al., PRD90,074039 (2014), BESIII, PRL 112, 022001 (2014)

The molecular implications of Y(4260)

The helicity angular distribution in Y(4260) to DD*pi process:



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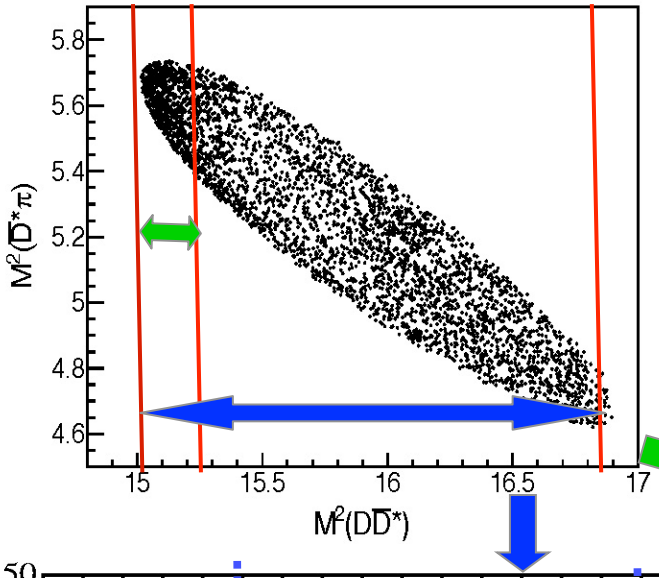
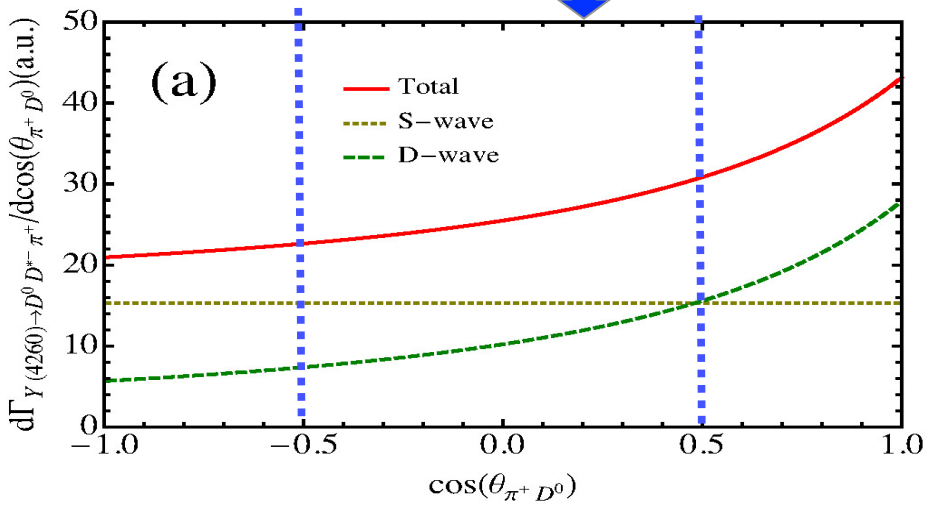
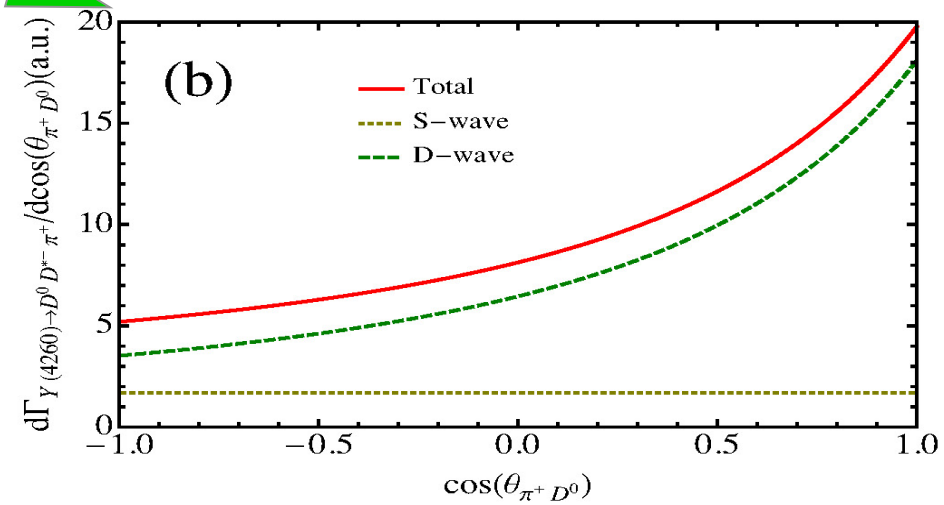


$$\mathcal{A} = \frac{n_{>0.5} - n_{<0.5}}{n_{>0.5} + n_{<0.5}} = (0.12 \pm 0.06)$$

$$\mathcal{A}_S = 0.0, \quad \mathcal{A}_D = 0.11, \quad \mathcal{A}_{S+D} = 0.05$$





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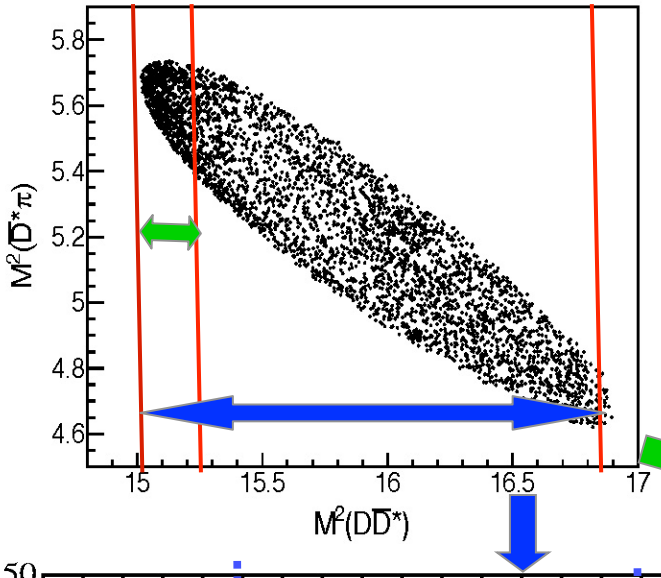

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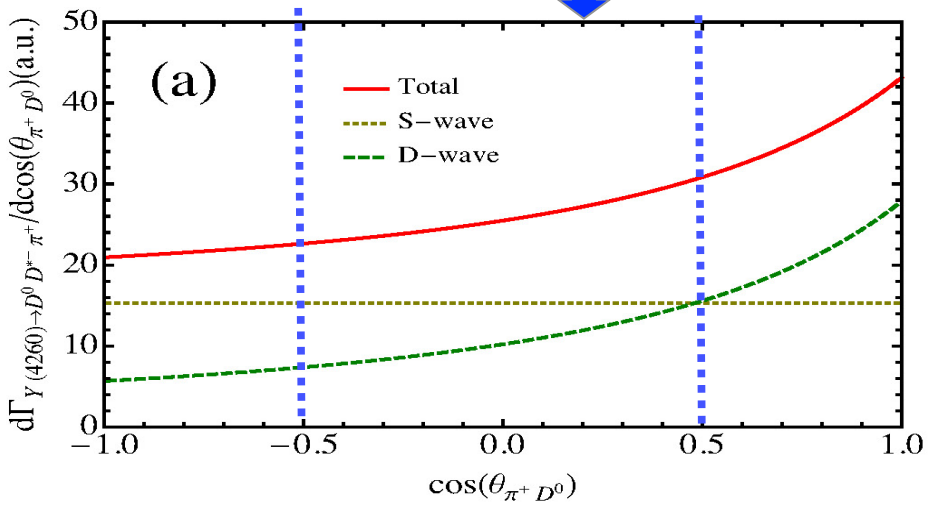
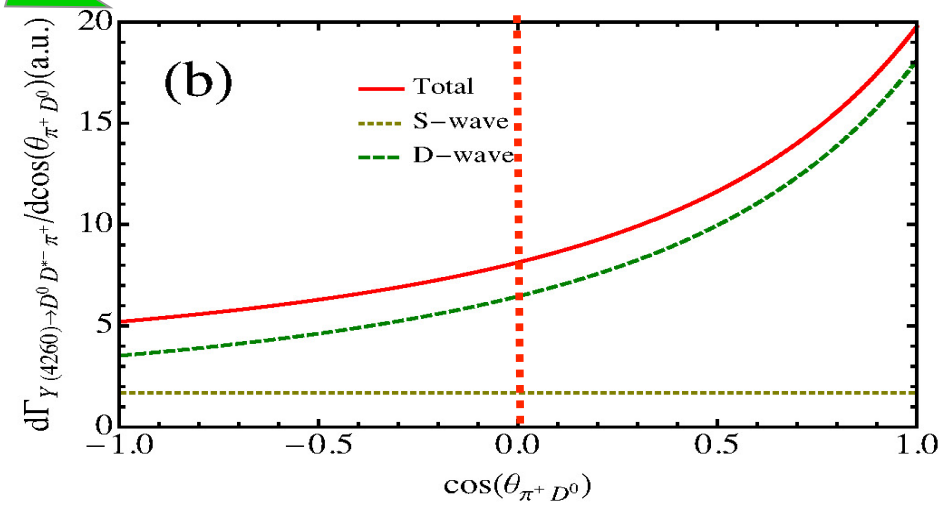
$$\mathcal{A}_{fb} = \frac{n_{>0} - n_{<0}}{n_{>0} + n_{<0}} .$$

$$\mathcal{A}_{bfS} = 0.0, \quad \mathcal{A}_{bfD} = 0.37, \quad \mathcal{A}_{bfS+D} = 0.16$$





The forward and backward asymmetry is sensitive to the nature of Y(4260)

M. Cleven, et al., PRD90,074039 (2014), BESIII, PRL 112, 022001 (2014)

Summary and outlook

Summary

- DD* π is the dominant decay mode if Y(4260) is dominated by the D_1D molecule.
- The Jackson angular distribution could be flat even D-wave is dominant.
- The helicity angular distribution at lower DD* invariant mass is sensitive the D_1D molecular picture
- For the time being, D_1D molecular explanation agrees with all the experimental data

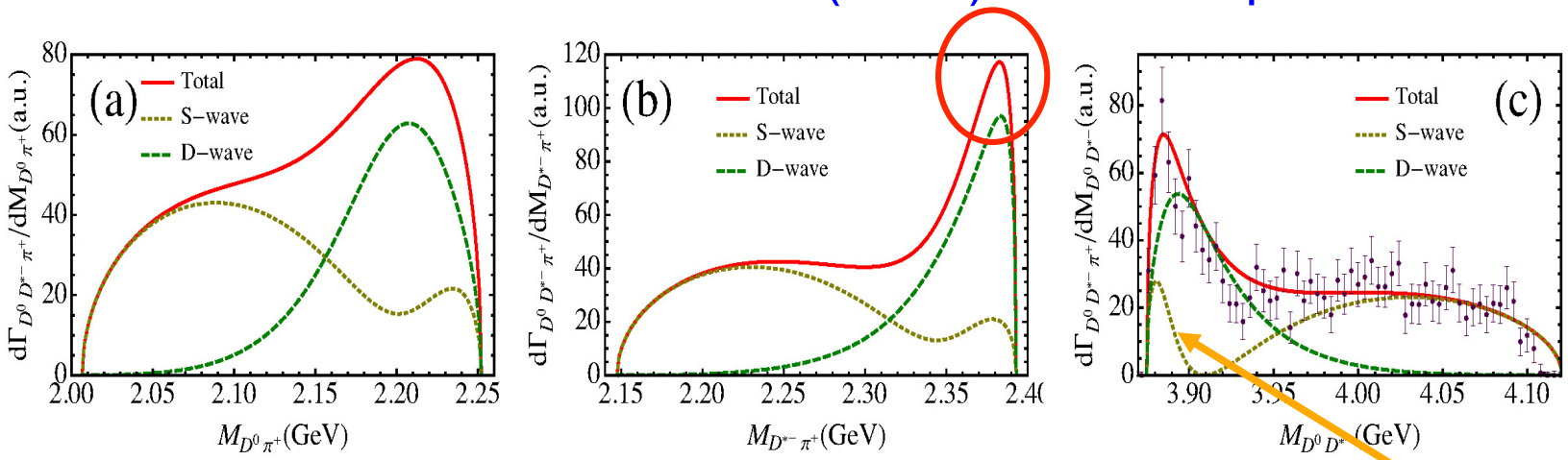
Outlook

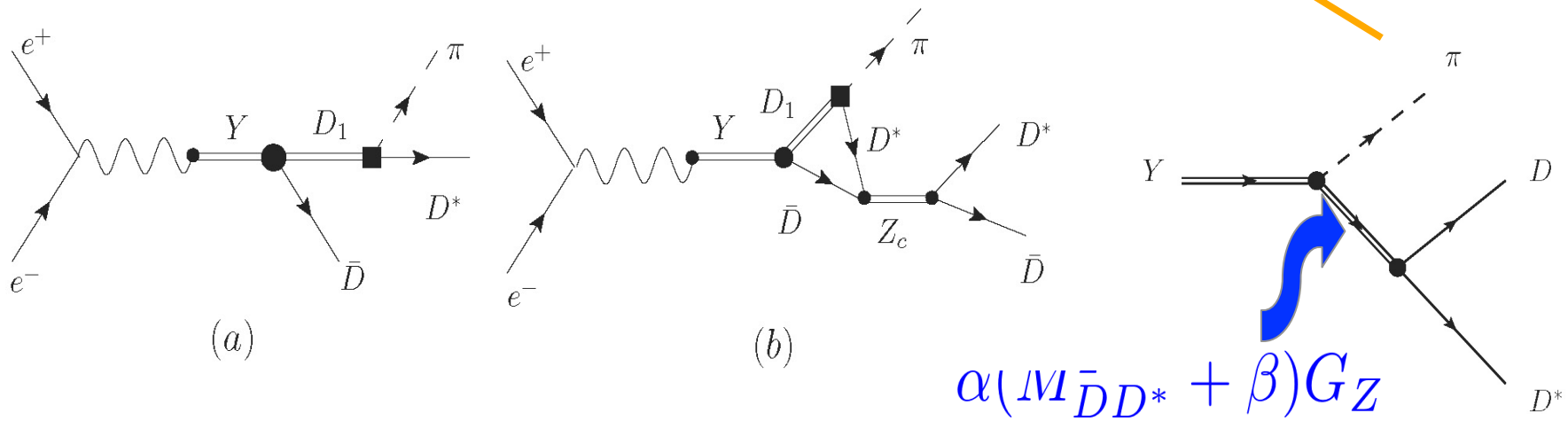
- The dynamic analysis of D_1D, D_1D^* and D_2D^* is a demanding task.
- The overall fit of the relevant channels is necessary to extract the physical parameters, such as the masses and widths.

Thanks for your attention!

The molecular implications of Y(4260)

The invariant mass distributions in Y(4260) to DD* π process





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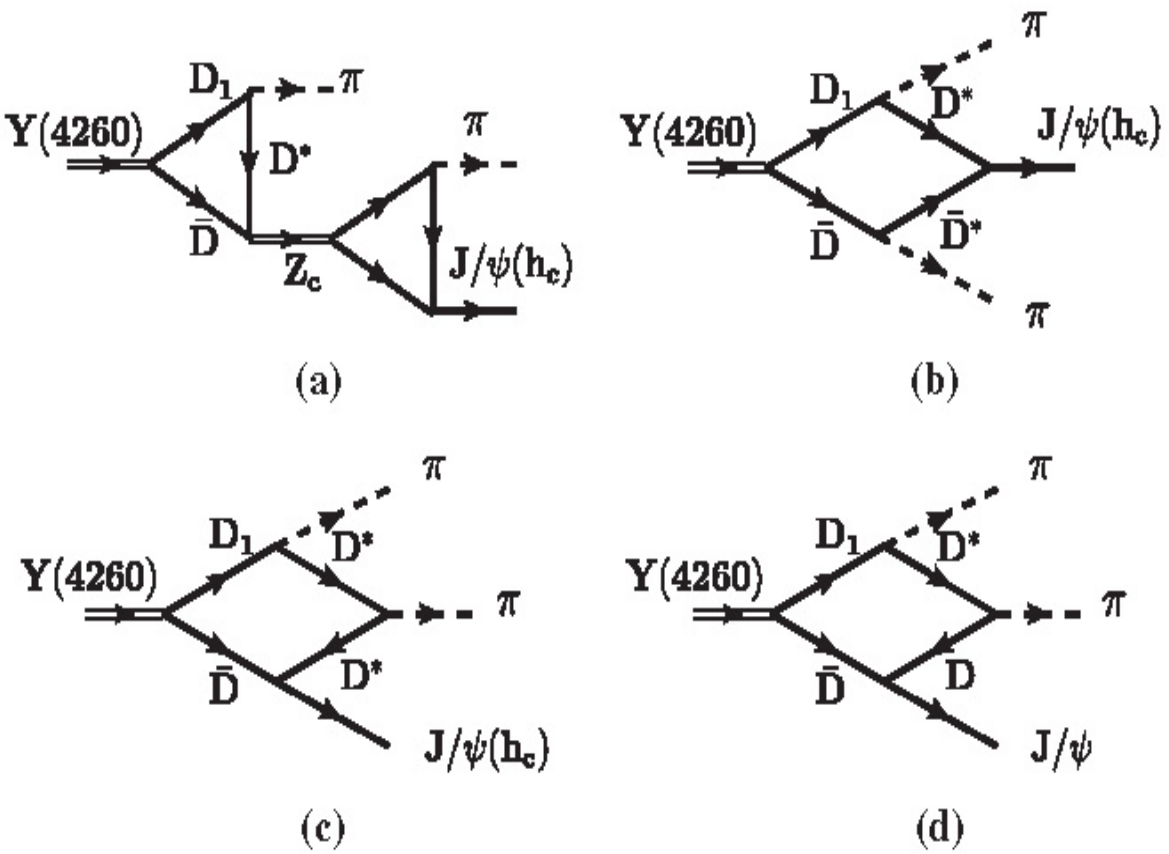
Y(4260)
D1
π
D*
D̄
Zc
π
J/ψ(hc)
(a)
Y(4260)
D1
π
D*
J/ψ(hc)
D̄
D̄*
π
(b)
Y(4260)
D1
π
D*
π
D̄
D*
J/ψ(hc)
(c)
Y(4260)
D1
π
D*
π
D̄
D
J/ψ
(d)