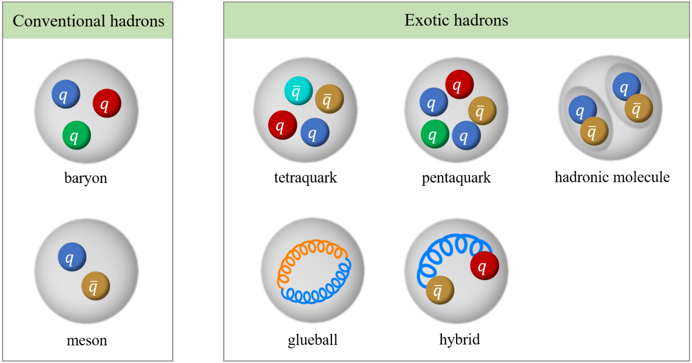
Prediction of a narrow exotic hadronic state with quantum numbers $J^{PC} = 0^{--}$

Teng Ji

Based on T. Ji, X.-K. Dong, F.-K. Guo and B.-S. Zou, arXiv:2205.10994

August 10,2022

Background



- Exotic quantums number such as $J^{PC} = 0^{--}, 0^{+-}, 1^{-+}$.
- Some of 1^{-+} have been observed such as $\pi_1(1400), \pi_1(1600), \eta_1(1855)$.
- No 0^{--} has been observed yet.

Framework

Table 1: The hadronic molecules considered in this work and their possible experimental candidates. The masses with † are the experimental values of their candidates.

Molecule	Components	J^{PC}	Candidates	Mass (GeV)	E_B MeV
$\psi(4230)$	$\frac{1}{\sqrt{2}}(D\bar{D}_1 - \bar{D}D_1)$	1^{--}	$\psi(4230)$	$4.220 \pm 0.015^{\dagger}$	67 ± 15
$\psi(4360)$	$\frac{1}{\sqrt{2}}(D^*\bar{D}_1 - \bar{D}^*D_1)$	1^{--}	$\psi(4360)$	$4.368 \pm 0.013^{\dagger}$	62 ± 14
$\psi(4415)$	$\frac{1}{\sqrt{2}}(D^*\bar{D}_2 - \bar{D}^*D_2)$	1^{--}	$\psi(4415)$	$4.421 \pm 0.004^{\dagger}$	49 ± 4
$\psi_0(4360)$	$\frac{1}{\sqrt{2}}(D^*\bar{D}_1 + \bar{D}^*D_1)$	0^{--}	-	-	-

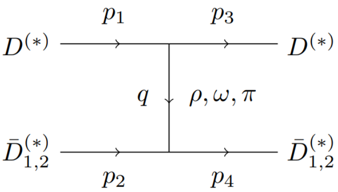


Figure 1: Feynman diagrams for the t channel P, V-exchange potential.

- $\mathcal{M}_{ij} = \frac{A^V_{ij}}{q^2+m_V^2} + \frac{A^P_{ij}}{q^2+m_P^2} + c_V B^V_{ij} + c_P B^P_{ij}$.
- $\psi(4230), \psi(4360)$ & $\psi(4415)$ as inputs.
- Defining $\chi^2 = \sum_i \left(\frac{E_{B,ii} - E^{\text{cen}}_{\text{exp},ii}}{E^{\text{err}}_{\text{exp},ii}}\right)^2$.
- Minimizing χ^2 to obtain proper c_V, c_P, Λ.
- Predicting the properties of $\psi_0(4360)$.

t-channel results

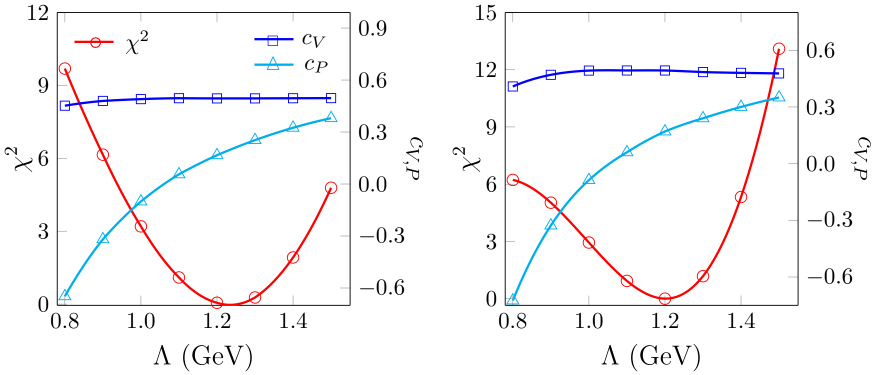


Figure 2: The best fitting for the single-channel (left) and coupled-channel (right) cases whose $c_V = 0.50$, $c_P = 0.18$

u channel considered

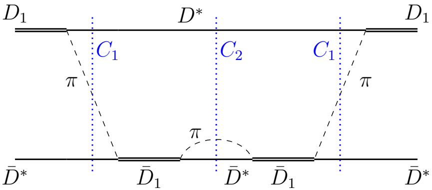


Table 2: Pole positions relative to the $D^* \bar{D}_1$ threshold in units of MeV with $c_V = 0.50$, $c_P = 0.18$ from the single t-channel fitting.

System	1^{--}		0^{--}	
t-channel	-63.5 ± 13.8		-72.4 ± 17.4	
g_S	g_{S0}	g_{S1}	g_{S0}	g_{S1}
C_2	$-61.5 - 3.5i$	$-61.5 - 9.2i$	$-70.0 - 3.5i$	$-70.0 - 8.9i$
$C_1 \& C_2$	$-65.8 - 6.6i$	$-73.1 - 14.2i$	$-65.8 - 0.30i$	$-59.4 - 1.1i$

We predict $m_{\psi_0} = 4366 \pm 18$ MeV and $\Gamma_{\psi_0} < 10$ MeV.

Experimental search

- The only channel for $\psi_0(4360)$ production in e^+e^- annihilation at $\sqrt{s} \sim 5$ GeV is P-wave $\eta\psi_0(4360)$.
- Hard to be distinguished from $\eta\psi(4360)$ with only invariant mass distribution of, e.g., $D\bar{D}^*$.
- Angular distribution is necessary.

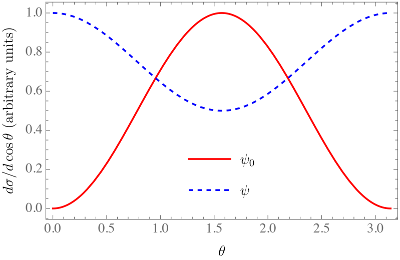


Figure 3: Angular distribution of $e^+e^- \to \eta\psi_{(0)}$. θ is the angle between the outgoing η and initial e^+e^- beam.

Summary

- Exotic $D^*\bar{D}_1$ molecules denoted as $\psi_0(4360)$ has been predicted from **t-channel** meson exchange.
- **Contact terms** are determined by reproducing the **experimental values** of $\psi(4230)$, $\psi(4360)$ and $\psi(4415)$ binding energies.
- Coupled-channel effects are found **negligible**.
- 3-body effects to the $D^*\bar{D}_1$ molecules are investigated.
- The effects of **u-channel π exchange** will change the binding energy by $\lesssim 10\ \mathrm{MeV}$, not change the qualitative conclusions.
- $\psi_0(4360)$ can be searched for in the $D^*\bar{D}^*$ final state in $e^+e^- \to \eta\psi_0 \to \eta D\bar{D}^*$ and it is **distinguishable** from $e^+e^- \to \eta\psi \to \eta D\bar{D}^*$.

Thank You!