The general propagator for S-wave threshold states

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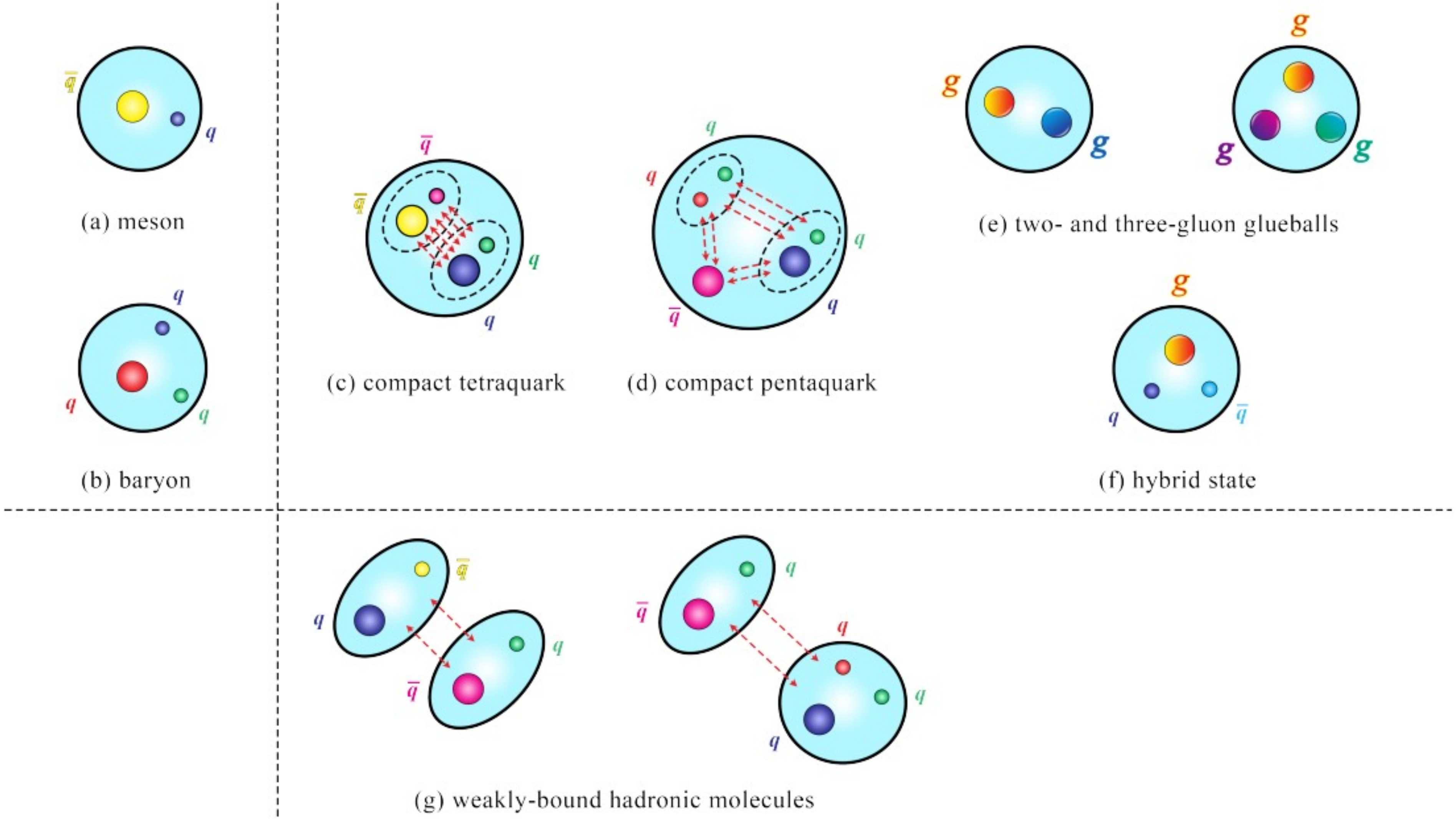
arxiv:2401.03373，arxiv:2401.00411

Outline

- Introduction
- The propagator in EFT incorporating Weinberg's compositeness theorem
- Study on $X(3872)$ using the propagator
- Summary


(a) meson
(b) baryon
(c) compact tetraquark
(d) compact pentaquark
(e) two- and three-gluon glueballs
(f) hybrid state
(g) weakly-bound hadronic molecules

Weinberg's compositeness theorem

$$a = [2(1-Z)/(2-Z)]/\sqrt{2\mu B} + \mathcal{O}(m_\pi^{-1})$$

$$r = -[Z/(1-Z)]/\sqrt{2\mu B} + \mathcal{O}(m_\pi^{-1})$$

Weinberg S. Phys. Rev., 1963, 130: 776
Weinberg S. Phys. Rev. B, 1965, 137: 672

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Relations: $g^2 = \frac{2\pi\sqrt{2\mu B}}{\mu^2}(1-Z)$, $g_0^2 = g^2/Z$, $B_0 = \frac{2-Z}{Z}B$

The propagator for the S-wave near-threshold state is written as

$$\mathrm{G_X}(E) = \frac{iZ}{D_{EFT}(E)}, \qquad D_{EFT}(E) = E + B + \widetilde{\Sigma}'(E) + i\,\Gamma/2\,,$$

$$\widetilde{\Sigma}'(E) = -g^2[\frac{\mu}{2\pi}\sqrt{-2\mu E - i\epsilon} + \frac{\mu\sqrt{2\mu B}}{4\pi B}(E-B)].$$

For a two-body channel, denoted as DD, with a threshold M_{th} and a near-threshold state X with mass M and width Γ.

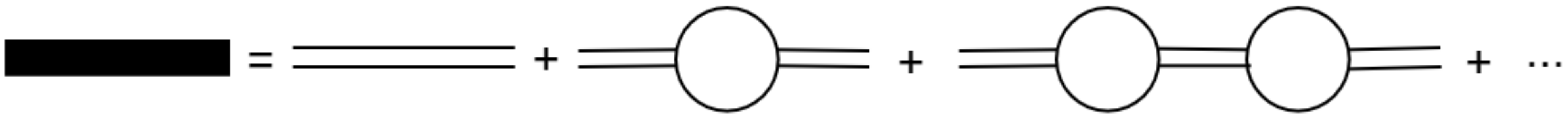


Figure. Full propagator for the near-threshold state.
The double line denotes the bare state.

The full propagator can be rewritten as

$$i\Delta = \frac{iZ}{2E + (2-Z)B - g^2 \frac{\mu}{2\pi}\sqrt{-2\mu E - i\epsilon} + iZ\,\Gamma_0/2}$$

$$= \frac{iZ}{E + B - g^2 \frac{\mu}{2\pi}\sqrt{-2\mu E - i\epsilon} - (1-Z)(E-B) + iZ\,\Gamma_0/2}$$

$$= \frac{iZ}{E + B - g^2 \frac{\mu}{2\pi}\sqrt{-2\mu E - i\epsilon} - g^2 \frac{\mu\sqrt{2\mu B}}{4\pi B}(E-B)] + iZ\,\Gamma_0/2}$$

We can find $\boldsymbol{\Gamma = Z\Gamma_0}$

For $X(3872)$, we may also consider the charged DD channel. The full propagator, which include the charged DD channel, can be written as

$$G_{X(3872)} = \frac{iZ}{E + B + \widetilde{\Sigma}'(E) + i\,\Gamma/2},$$

$$\widetilde{\Sigma}'(E) = -g^2\left[\frac{\mu}{2\pi}\sqrt{-2\mu E - i\epsilon} + \frac{\mu\sqrt{2\mu B}}{4\pi B}(E - B)\right] -$$

$$g_c^2\left[\frac{\mu_c}{2\pi}\sqrt{-2\mu_c(E-\delta) - i\epsilon} + \frac{\mu_c\sqrt{2\mu_c(B+\delta)}}{4\pi(B+\delta)}(E - B - 2\delta)\right].$$

- Breit-Wigner amplitude:

$$f(E)=\frac{1}{D_{BW}(E)},D_{BW}(E)=E+B+i\,\Gamma/2$$

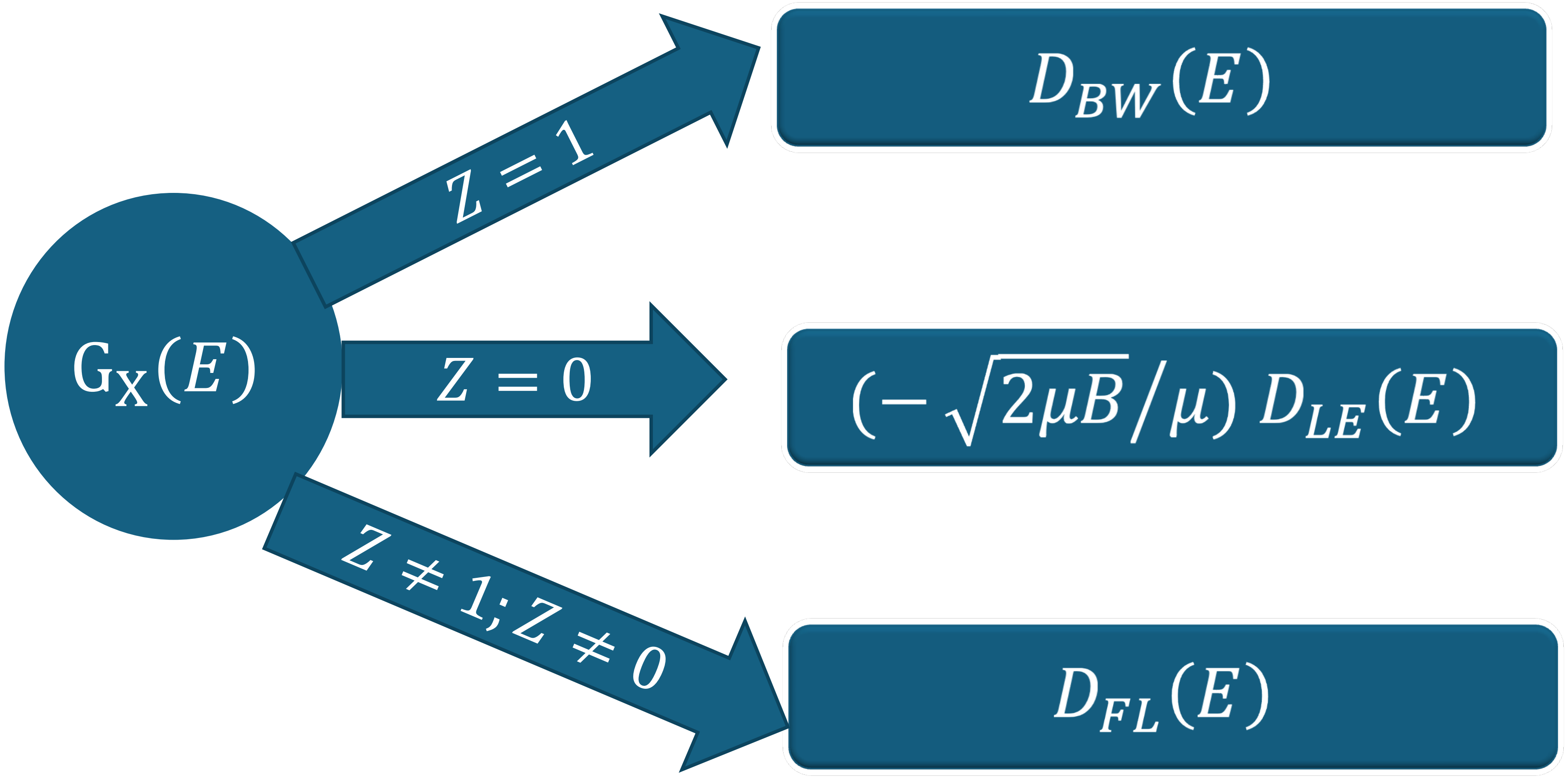
- Flatté amplitude:

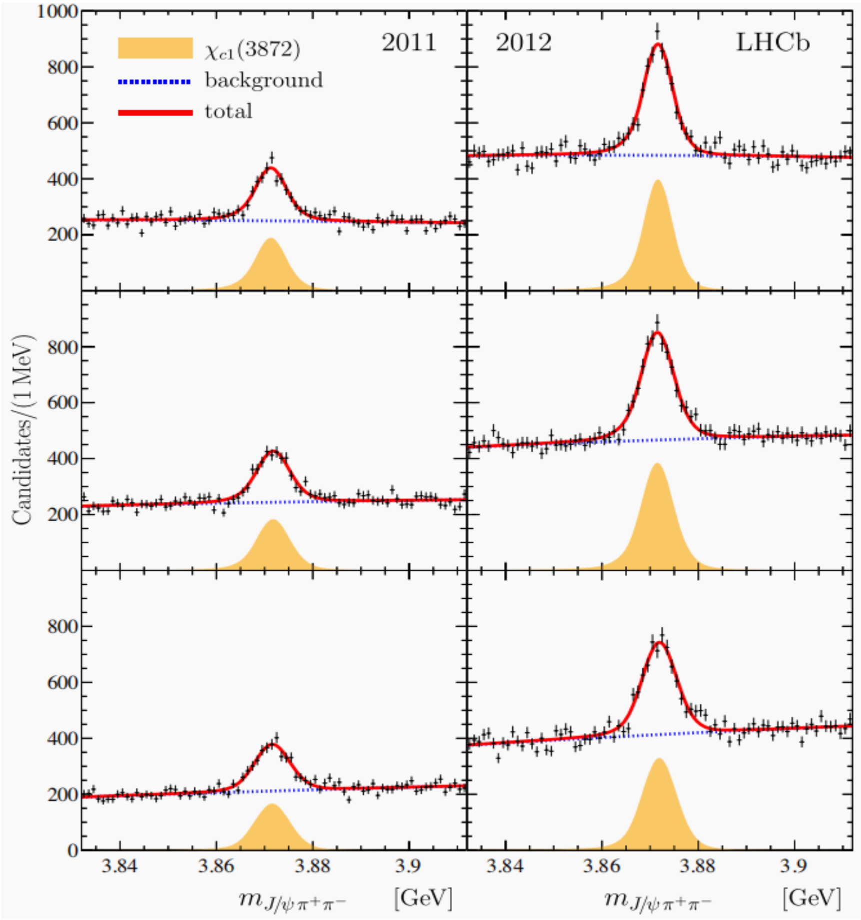
$$f(E)=\frac{1}{D_{FL}(E)},D_{FL}(E)=E-E_f-\frac{1}{2}g_1\sqrt{-2\mu E}+i\frac{1}{2}\Gamma_f$$

- Low-energy scattering amplitude:

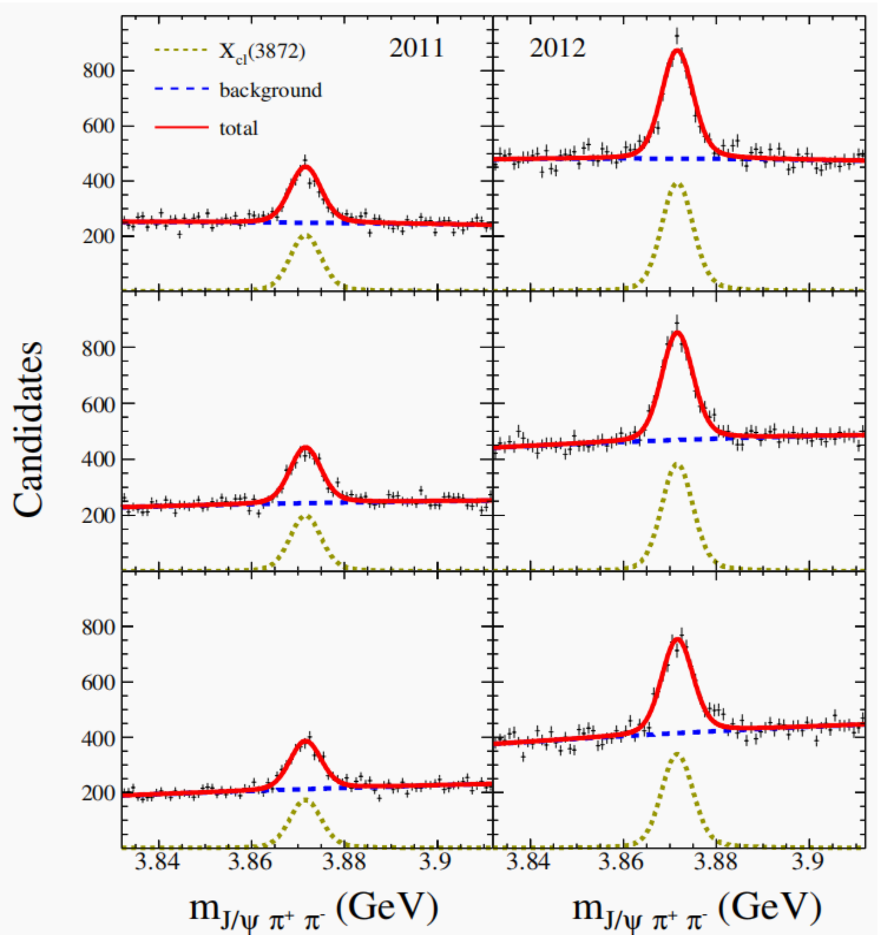
$$f(E)=\frac{1}{D_{LE}(E)},D_{LE}(E)=-1/a+\sqrt{-2\mu E-i\epsilon}$$

S. M. Flatte, Phys. Lett. B 63 (1976) 224–227.
E. Braaten and M. Lu, Phys. Rev. D 76 (2007) 094028.


$G_X(E)$
$Z = 1$
$Z = 0$
$Z \neq 1; Z \neq 0$
$D_{BW}(E)$
$\left(-\sqrt{2\mu B}/\mu\right) D_{LE}(E)$
$D_{FL}(E)$



Fitting result of LHCb Collaboration.



Our fitting result based on LHCb data.

Our fitting result of Z for $X(3872)$ is 0.42 ± 0.16 based on LHCb data.

R. Aaij et al. (LHCb), Physical Review D 102, 092005 (2020).
H. Xu, N. Yu, and Z. Zhang, arxiv:2401.00411.

Summary

- The propagator for near-threshold states in is general.
- The fitting result of Z for $X(3872)$ is non-vanishing based on LHCb data.
- We are analysing the Z for $X(3872)$ using the propagator considering the charged DD channel.

Thanks for your attention!