Nature of the D_0^* meson in $D\pi$ scattering with chiral symmetry

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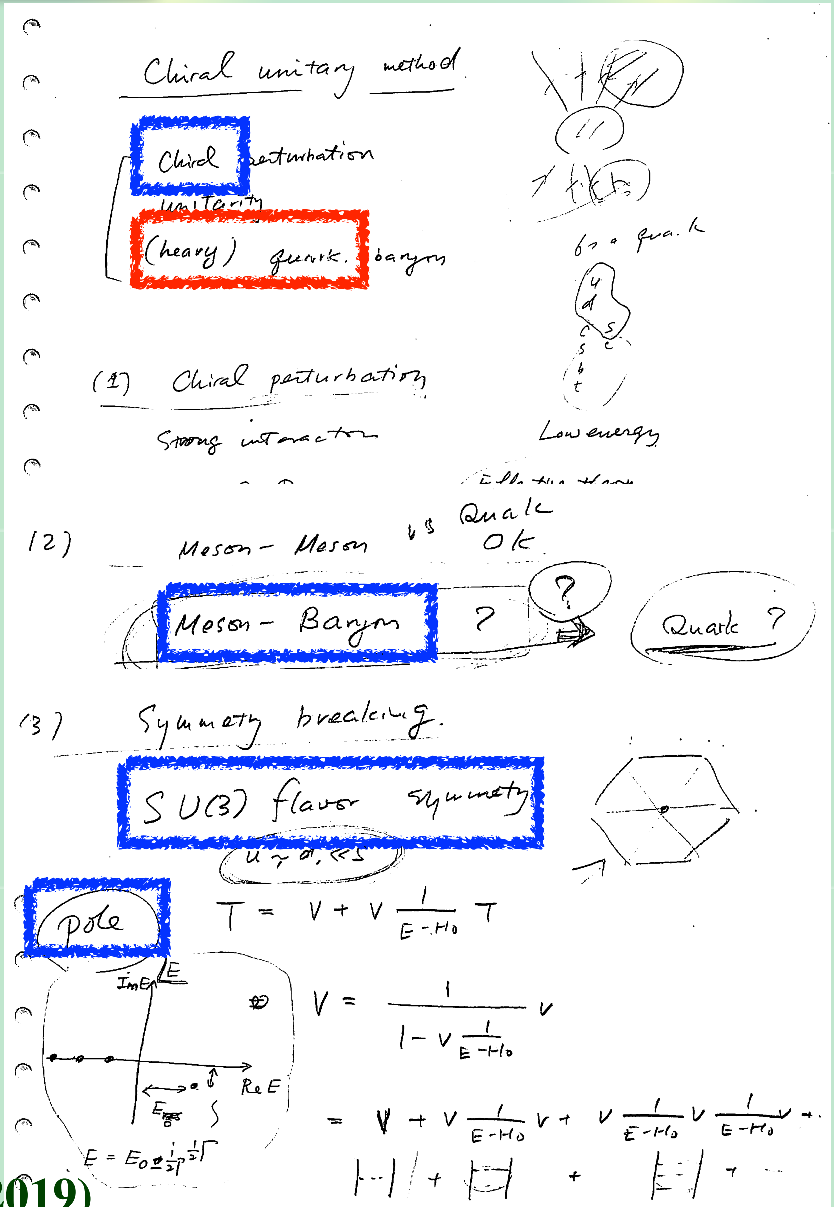
Some history

In 2001, summer…

- **first discussion on research**
- **chiral symmetry**
- **meson-baryon system**
- **SU(3) flavor symmetry**
- **resummation, pole**

—> $\Lambda(1405)$, **pentaquark** Θ^{+}, **…**



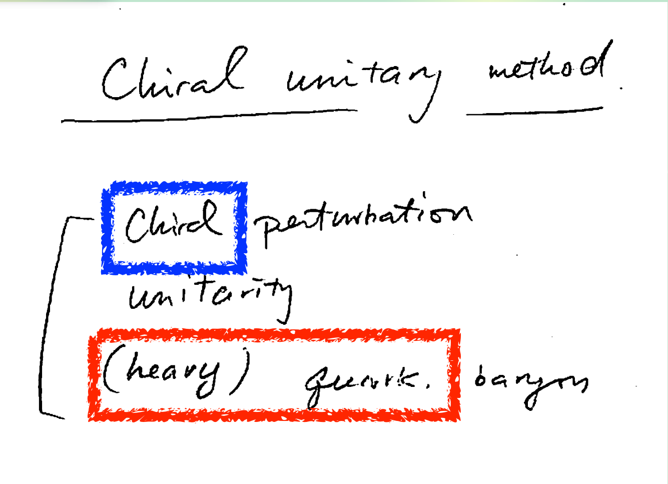
One more thing…

- **heavy quark?**

—> study of heavy-light meson

T. Sugiura, T. Hyodo, Phys. Rev. C99, 065201 (2019)

Effective Lagrangian



Heavy-light mesons $\sim c\bar{u}/c\bar{d}$

- **chiral symmetry: parity partner**

$$D(0^-) \leftrightarrow D_0^*(0^+)$$

- **heavy-quark symmetry: spin partner**

$$D(0^-) \leftrightarrow D^*(1^-), \quad D_0^*(0^+) \leftrightarrow D_1(1^+)$$

Effective Lagrangian (linear representation)

M.A. Nowak, M. Rho, I. Zahhed, Phys. Rev. D48, 4370 (1993);
W.A. Bardeen, C.T. Hill, Phys. Rev. D49, 409 (1994);
D. Suenaga, S. Yasui, M. Harada, Phys. Rev. C96, 015204 (2017).

$$\mathscr{L} = -\,\mathrm{Tr}\,[H_L(iv\cdot\partial)\bar{H}_L] - \mathrm{Tr}\,[H_R(iv\cdot\partial)\bar{H}_R] + \cdots$$

↑ ↑

linear combination of D, D^*, D_0^*, D_1

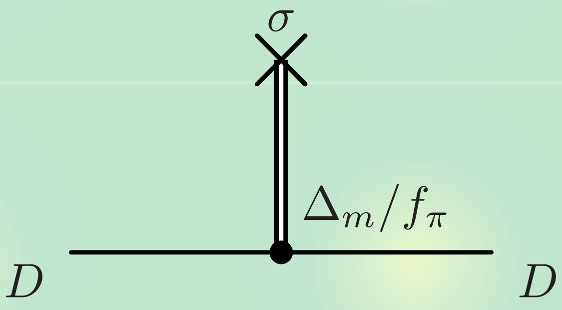
Decay width of D_0^*

Constraint from chiral symmetry

$$\mathscr{L} = \frac{\Delta_m}{2f_\pi}[2D\sigma D^\dagger - 2D_0^*\sigma D_0^{*\dagger} - 2iD_0^*\pi D^\dagger + 2iD\pi D_0^{*\dagger}] + \cdots$$

- **chiral condensate** $\langle\sigma\rangle = f_\pi$ **: mass splitting of** D **and** D_0^*

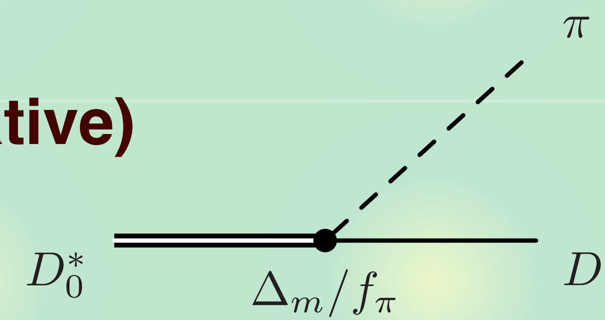
$$M_D = m - \frac{\Delta_m}{2}, \quad M_{D_0^*} = m + \frac{\Delta_m}{2}$$



- $D_0^* D\pi$ **coupling: same** Δ_m/f_π

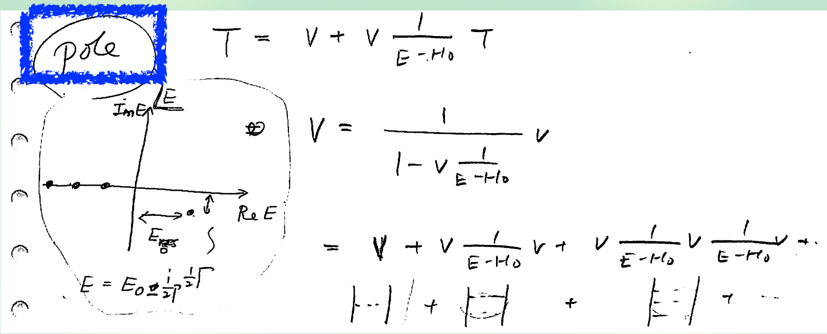
- $M_{D_0^*}$ **—> decay width of** $D_0^* \to D\pi$ **(perturbative)**

$$\Gamma_{\rm th} \sim 1000~\mathrm{MeV} \gg \Gamma_{\rm exp} \sim 250~\mathrm{MeV}$$



Pure chiral partner D_0^* is not consistent with data.

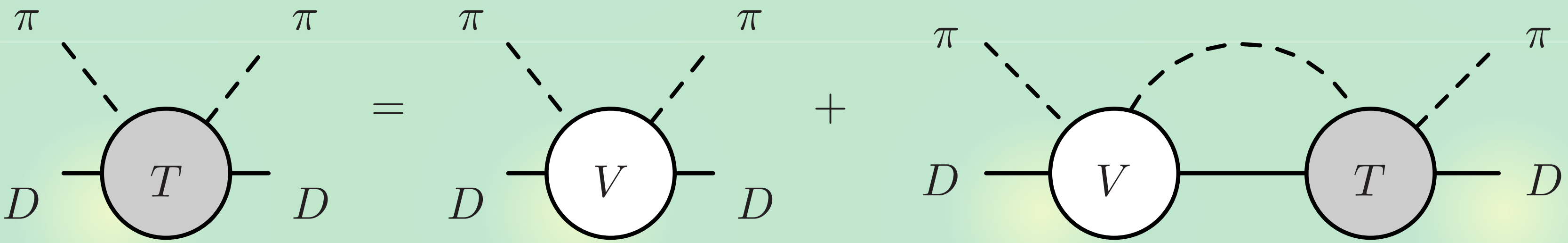
$D\pi$ scattering



What is missing?

- D_0^* is a resonance.
- Search for pole!

Description of $D\pi$ scattering



$$T = V + VGT$$

$$= V + VGV + VGVGV + \cdots$$

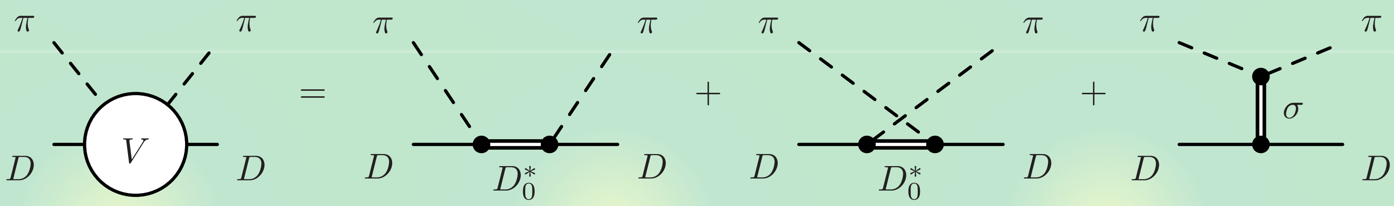
effective Lagrangian

- nonperturbative resummation

D_0^* can appear as a **pole** in scattering amplitude T

Low-energy theorem

Tree-level amplitude



- low-energy expans

$$V^{1/2} = \frac{3}{4}\frac{M_{D_0^*}^2 - M_D^2}{\bar{\sigma}^2}\left[-1 - \frac{2}{M_D^2} \right.$$

Chiral Symmetry in Hadron Physics

Methods and ideas of chiral symmetry

ハドロン物理におけるカイラル対称性ーー基本的な考え方と方法

原子核三者若手夏の学校２００２

保坂　淳（阪大、RCNP)

- chiral symmetry: $\mathcal{O}$

- Weinberg-Tomozawa th

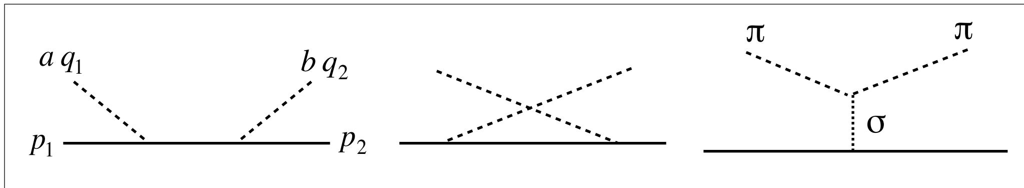


図4.3　線形σ模型でπN散乱に寄与するツリーグラフ

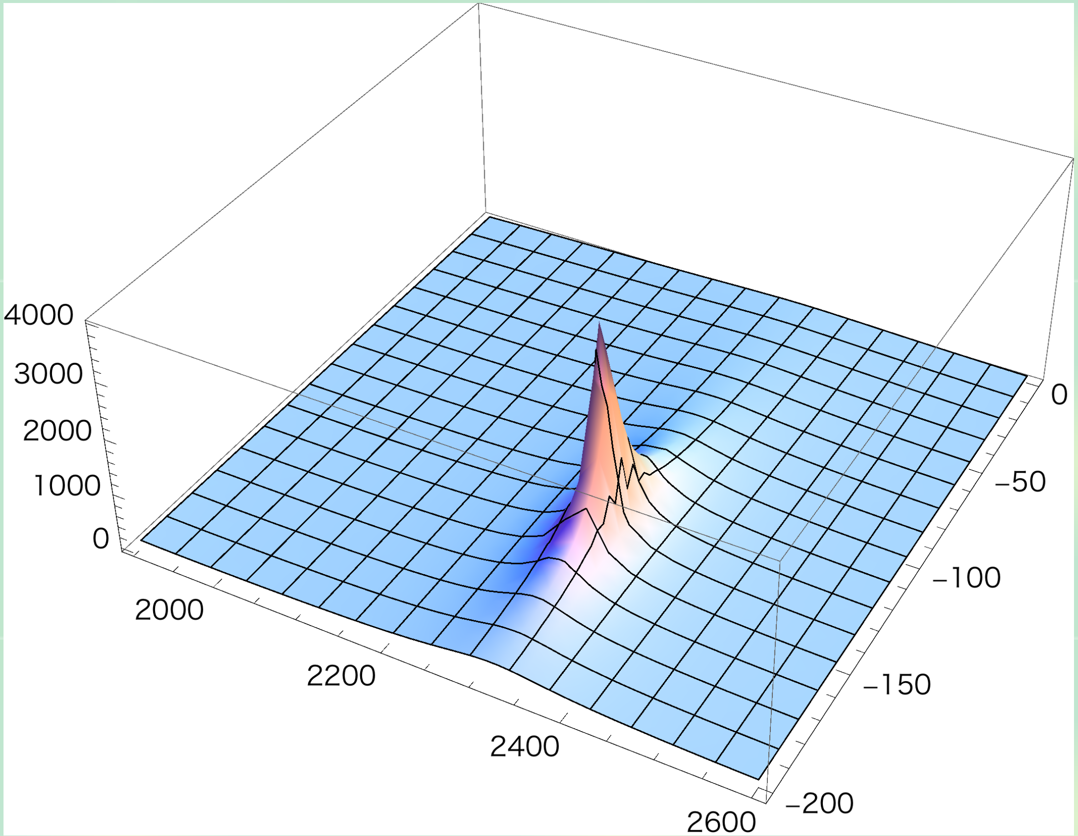
$$= -\frac{2M_D\omega}{\bar{\sigma}^2} + \mathcal{O}(Q^2),$$

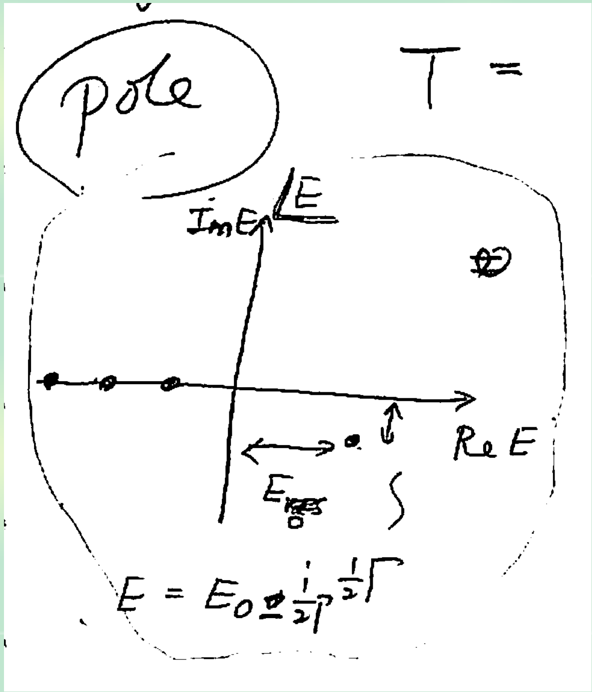
Low-energy theorem <— Inclusion of all possible diagrams

D_0^* pole

Scattering amplitude in the complex energy plane

- pole at $\sqrt{s} = 2318 - i135$ MeV : mass and width





PDG $2318 \pm 29 - i(134 \pm 20)$ MeV **can be reproduced.**

Nature of D_0^*

What is the nature of D_0^* ?

1) pure chiral partner

- perturbative calculation with linear sigma model
- too large decay width: $\Gamma_{\rm th} \sim 1000$ MeV $\gg \Gamma_{\rm exp} \sim 250$ MeV

2) pure dynamically generated molecule

- pole with nonlinear sigma model (no bare D_0^*)

M. Altenbuchinger, L.S. Geng, W. Weise, Phys. Rev. D89, 014026 (2014)

- too small mass: $M_{\rm th} \sim 2100$ MeV $< M_{\rm exp} \sim 2320$ MeV

3) chiral partner dressed by the $D\pi$ cloud

- PDG value is reproduced: OK

Summary

- **Heavy-light mesons serve as a testing ground for chiral and heavy-quark symmetries.**

- **Chiral low-energy theorem is guaranteed when all possible contributions are included.**

- D_0^* **can be interpreted as a chiral partner of** D **coupled with the** $D\pi$ **scattering states.**

  T. Sugiura, T. Hyodo, Phys. Rev. C99, 065201 (2019)

- **Follow advices from the supervisor.**