“New Hadrons” Workshop 2010
28 Feb 2011, Nishina Hall, RIKEN Wako Campus

Study of mixing properties of $a_1(1260)$

Hideko NAGAHIRO (Nara Women’s University)

Collaborators :
Kanabu Nawa, Sho Ozaki,
Daisuke Jido, Atsushi Hosaka

H. Nagahiro, K. Nawa, S. Ozaki, D. Jido and A. Hosaka, arXiv:1101.3623 [hep-ph]

Introduction

<u>Nature of axial vector meson $\boldsymbol{a_1}$**(1260)**</u> **:** m = 1230 ± 40 MeV, Γ=260 to 600 MeV [PDG]

<u>as an **elementary field** (or $q\bar{q}$) : candidate for the chiral partner of ρ</u>

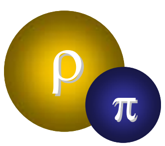
[$q\bar{q}$-NJL] M.Wakamatsu *et al*,. ZPA311(88)173, A.Hosaka, PLB244(90)363-367 , …

[Lattice QCD] M. Wingate *et al*., PRL74(95)4596, ...

[Hidden local sym.] Bando-Kugo-Yamawaki, PR164(88)217;
Harada-Yamawaki, PR381(03)1, Kaiser-Meissner, NPA519(90)671, …

[Holographic QCD] T. Sakai, S. Sugimoto, PTP113 (05) 843; *ibid.*114(05)1083, …

<u>as a **dynamically generated resonance [as πρ composite particle]**</u>



[coupled-channel BS] Lutz-Kolomeitsev, NPA730(04)392, …

[Chiral Unitary model] Roca-Oset-Singh, PRD72(05)014002, …
[$a_1 \to \pi\gamma$] Nagahiro-Roca-Hosaka-Oset, PRD79(09)014015, …

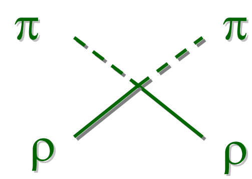
in coupled-channel approach based on the chiral effective theory

Physical a_1 = +

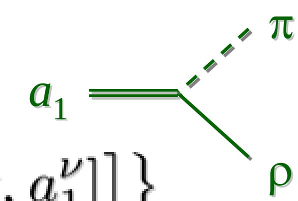
Lagrangians : holographic QCD (HQCD)

[Sakai, Sugimoto, PTP113(05)843; PTP114(05)1083, Nawa, Suganuma, Kojo, PRD75(07)086003 etc.]

$$\mathcal{L}_{\rm WT} = -\frac{g_4}{4f_\pi^2}\mathrm{tr}\left([\rho^\mu, \partial^\nu \rho_\mu][\pi, \partial_\nu \pi]\right)$$



$$\mathcal{L}_{a_1\pi\rho} = -g_{a_1\pi\rho}\frac{i\sqrt{2}}{f_\pi}\left\{\mathrm{tr}\left[(\partial_\mu a_{1\nu} - \partial_\nu a_{1\mu})[\partial^\mu \pi, \rho^\nu]\right] + \mathrm{tr}\left[(\partial_\mu \rho_\nu - \partial_\nu \rho_\mu)[\partial^\mu \pi, a_1^\nu]\right]\right\}$$



where

$g_4 = 1$, $g_{a1\pi\rho} = 0.26$

$f_\pi = 92.4$MeV, $m_\rho = 776$MeV

essentially the same as **those of the <u>hidden-local symmetry</u>**

<u>a_1 meson in holographic QCD</u>

» a_1 meson appears through the mode expansion of $A_\mu(x,z)$ [5D gauge field]

✓ elementary a_1 meson does ***not*** have molecular component [large Nc limit]

[E. Witten, Nucl. Phys. B 160, 57 (1979)]

→ Important concept to avoid the double-counting of molecule and bare comp.

✓ m_{a1}= 1189 MeV and couplings are determined automatically

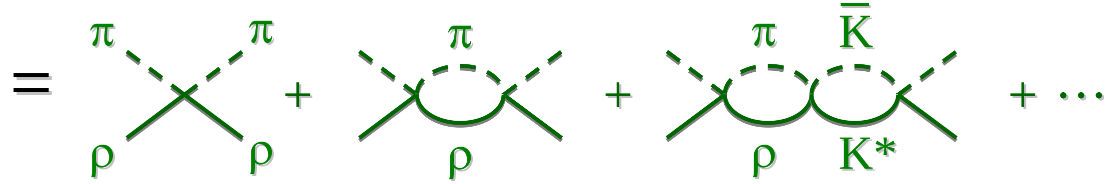
πρ → πρ scattering amplitude

composite a_1 meson [dynamically generated resonance in Chiral Unitary Approach]

Unitarized *s*-wave πρ scattering amplitude

[L.Roca, E.Oset and J.Singh, PRD72(05)014002]

$$t_{\mathrm{WT}}(s) = \frac{v_{\mathrm{WT}}}{1 - v_{\mathrm{WT}} G}$$



$\sqrt{s_p}$ = 1011–84*i* MeV (πρ + K*K̄) [Roca05]… $a_{pheno.} = -1.85$

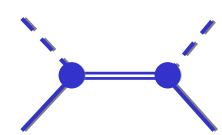
$\sqrt{s_p}$ = 1012–221*i* MeV (πρ only) …………… $a_{nat.} = -0.2$ †

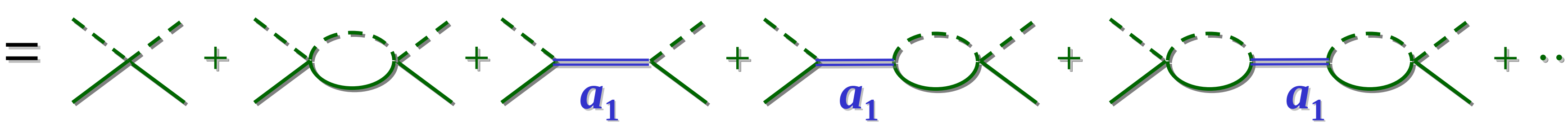
†Natural value
Hyodo-Jido-Hosaka
PRC78(08)025203

elementary a_1 meson [through an additional interaction]

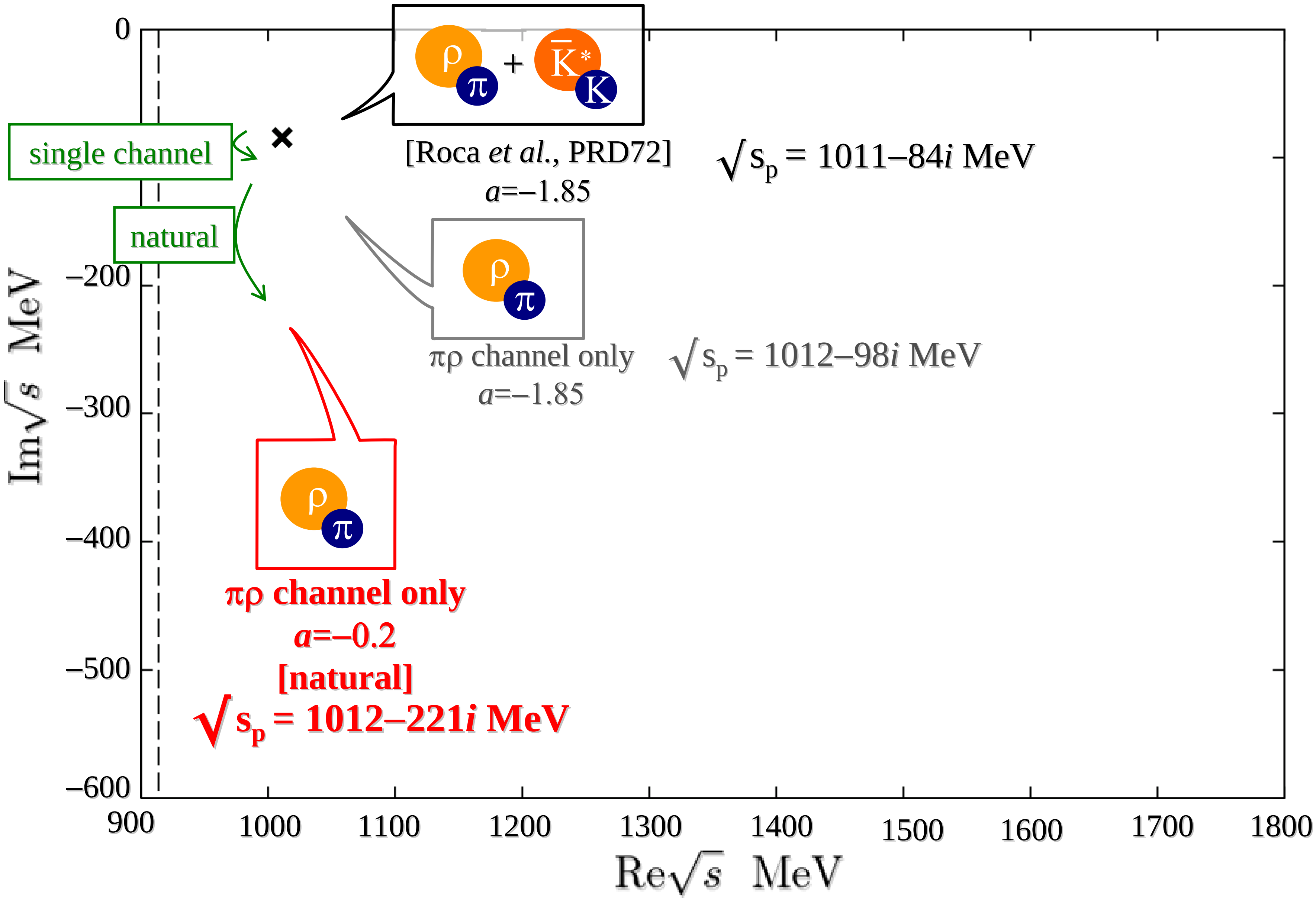
$$T_{\mathrm{full}}(s) = \frac{v_{\mathrm{WT}} + v_{a1}}{1 - (v_{\mathrm{WT}} + v_{a1})\, G}$$

$v_{a1} =$

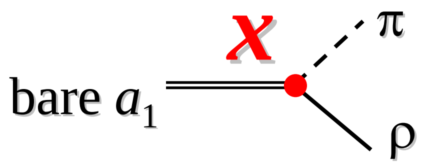


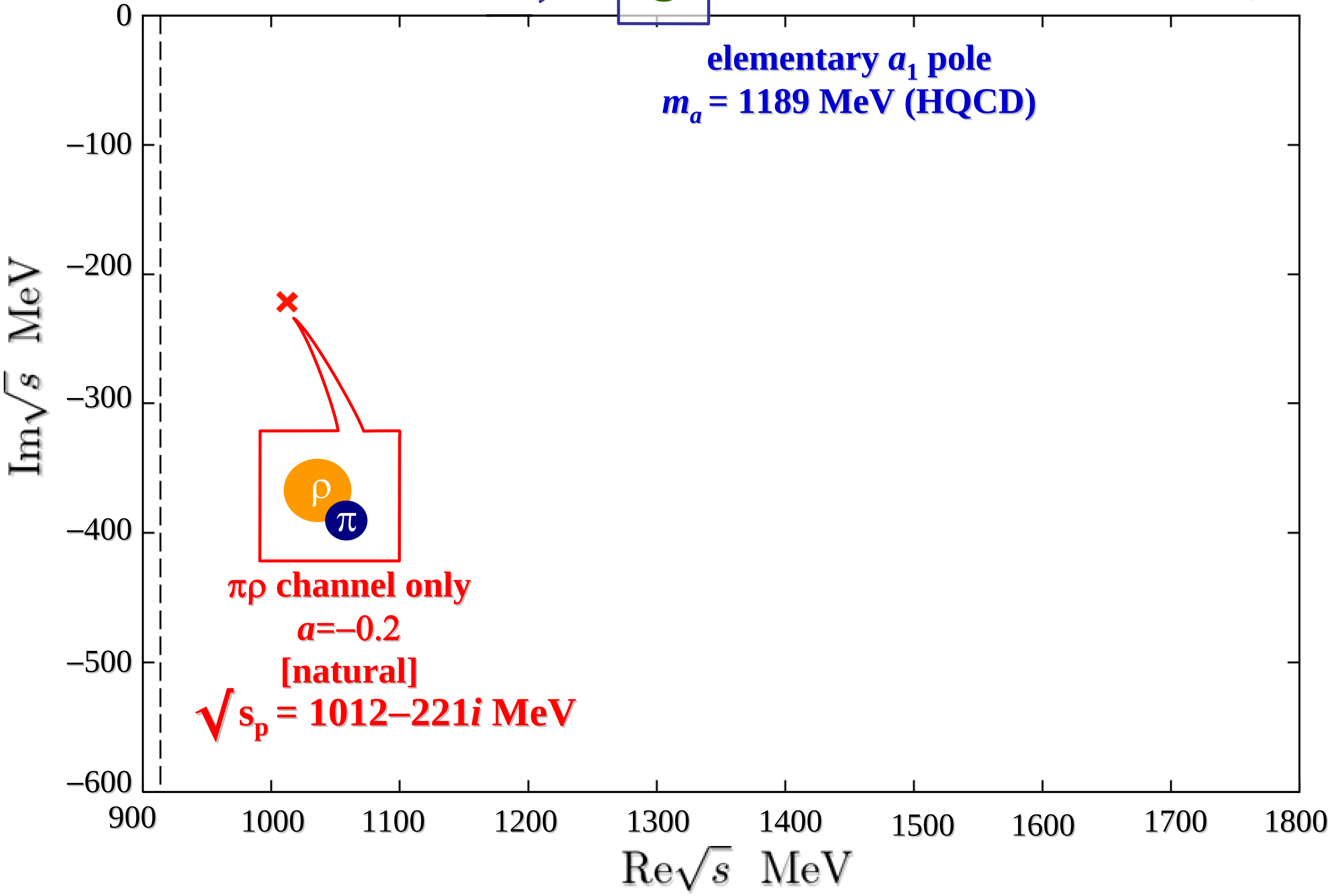


Numerical result 1 : pole-flow of T-matrix

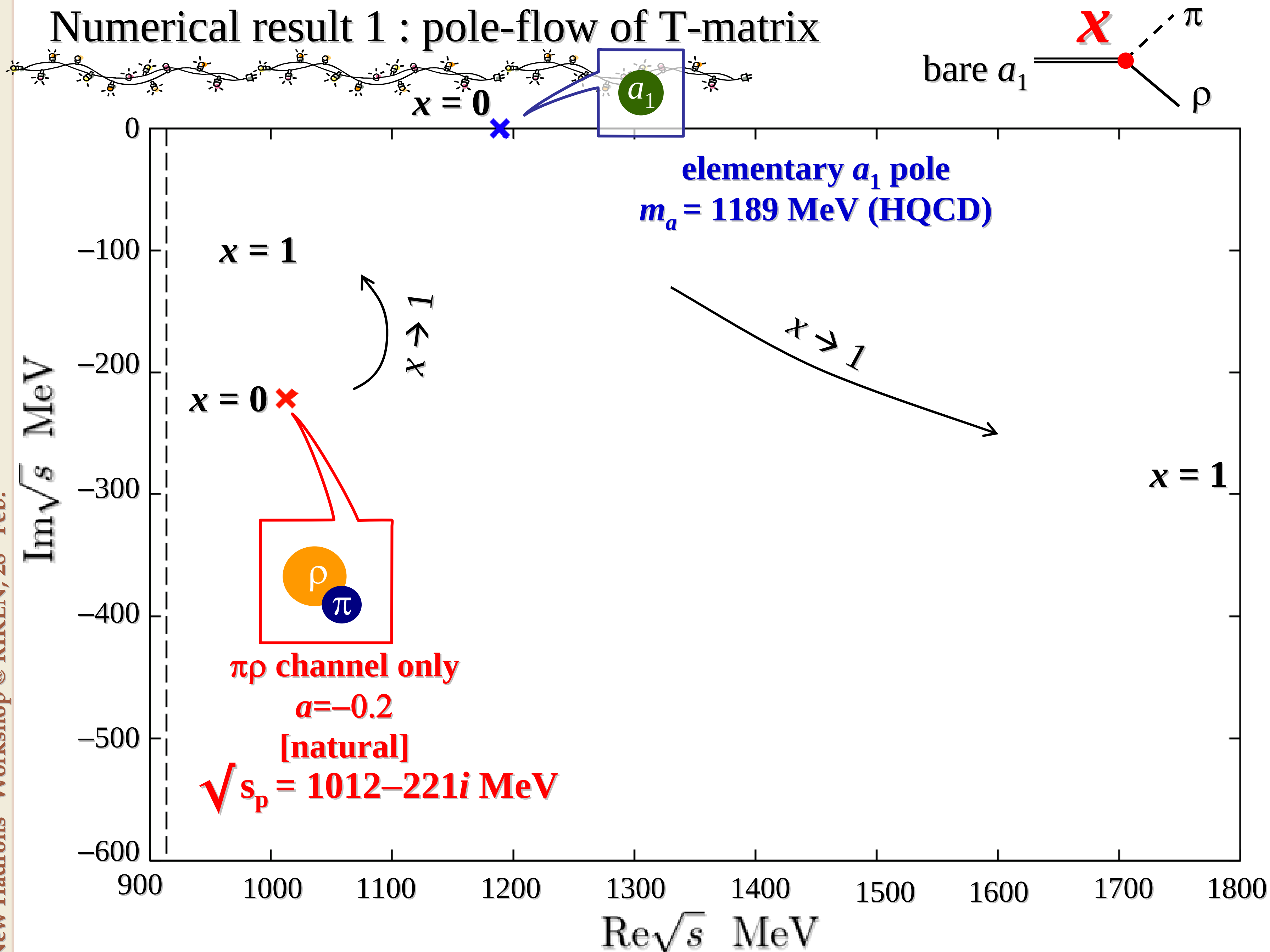


Numerical result 1 : pole-flow of T-matrix

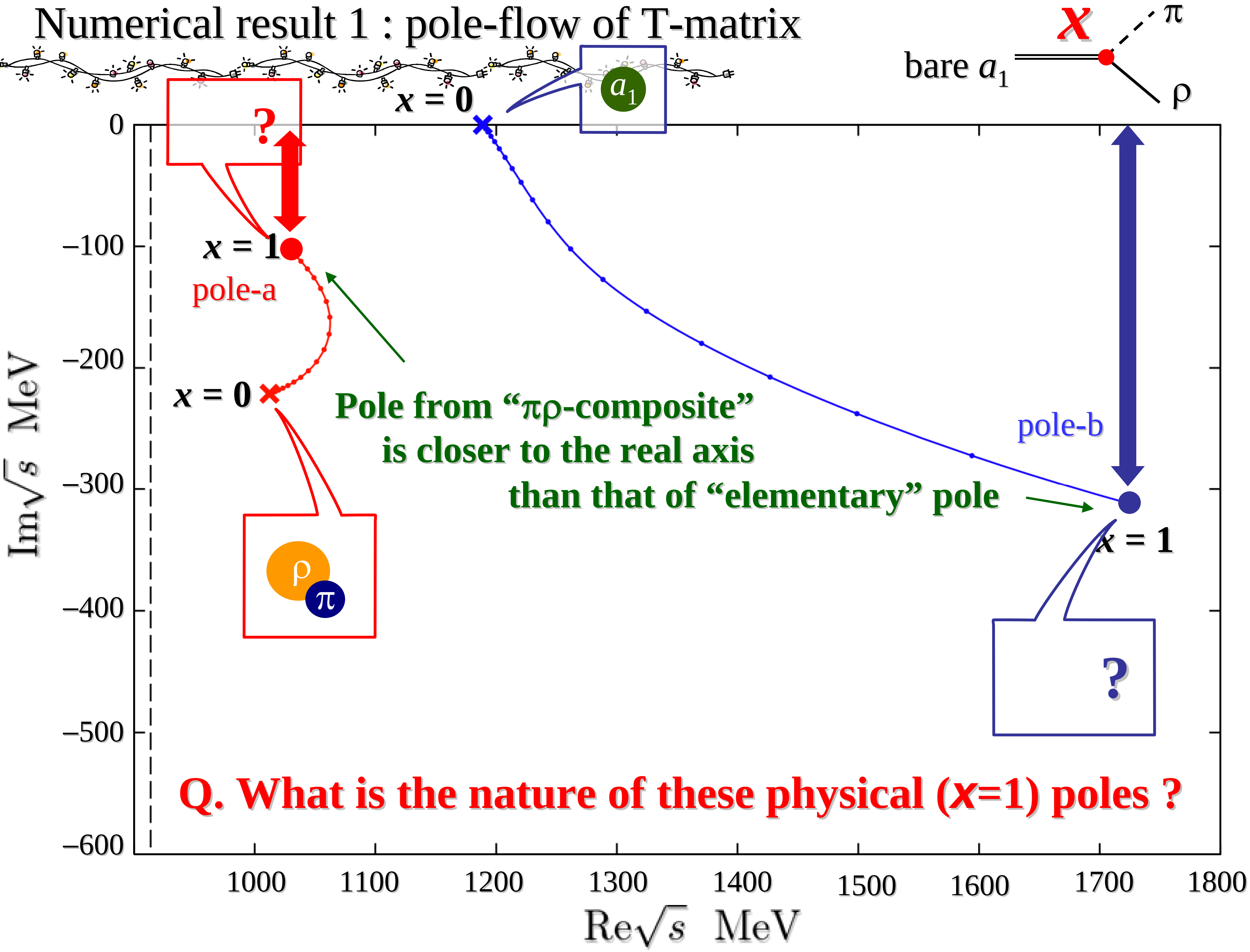




Numerical result 1 : pole-flow of T-matrix

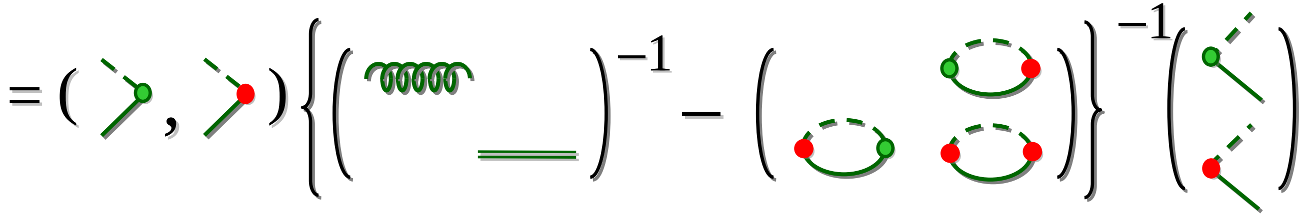


Numerical result 1 : pole-flow of T-matrix



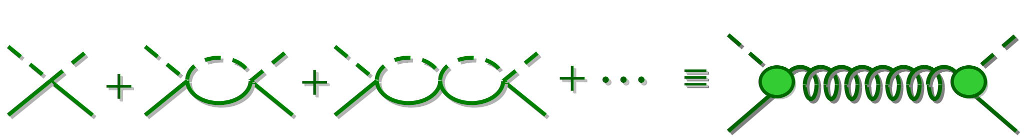
Alternative expression for the full πρ scattering amplitude T

$$T = \frac{v_{WT} + v_{a_1}}{1 - (v_{WT} + v_{a_1})G} = (g_R, g)\left\{\begin{pmatrix} s-s_p & \\ & s-m_{a1}^2 \end{pmatrix} - \begin{pmatrix} & g_R G g \\ g G g_R & g G g \end{pmatrix}\right\}^{-1}\begin{pmatrix} g_R \\ g \end{pmatrix}$$



πρ-composite a_1 pole

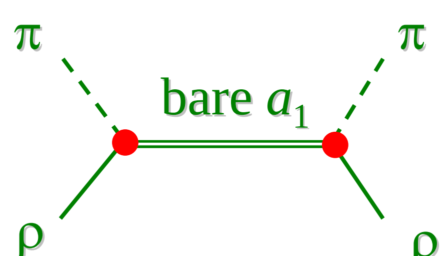
$$T_{WT} = \frac{v_{WT}}{1 - v_{WT}G}$$



$$= g_R(s)\frac{1}{s - s_p}g_R(s)$$

a_1 pole term

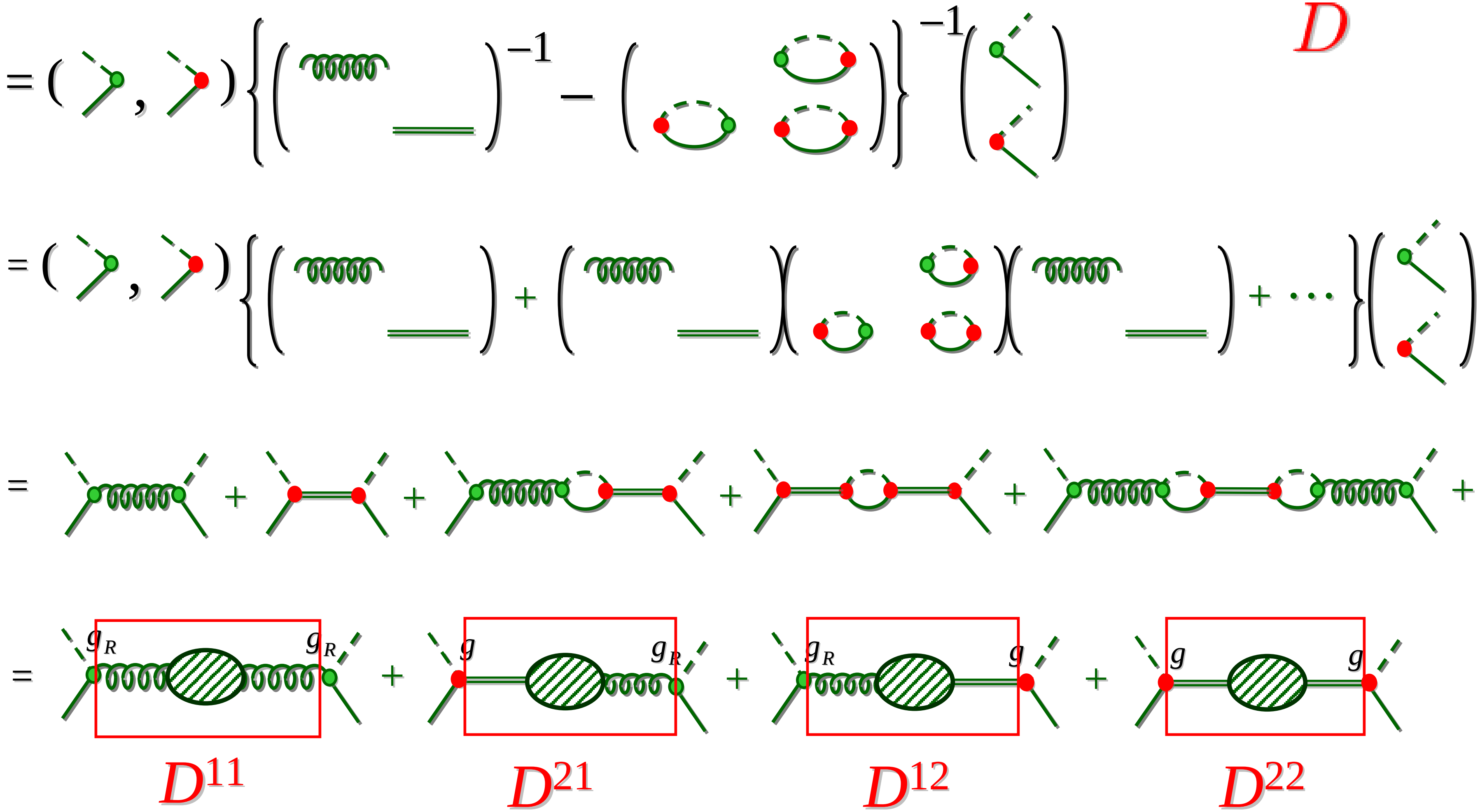
$$V_{a_1} = g(s)\frac{\vec{\epsilon}\cdot\vec{\epsilon}'}{s - m_a^2}g(s)$$



Alternative expression for the full πρ scattering amplitude T

$$T = \frac{v_{WT} + v_{a_1}}{1 - (v_{WT} + v_{a_1})G} = (g_R, g)\left\{\begin{pmatrix} s-s_p & \\ & s-m_{a1}^2 \end{pmatrix} - \begin{pmatrix} & g_R G g \\ g G g_R & g G g \end{pmatrix}\right\}^{-1}\begin{pmatrix} g_R \\ g \end{pmatrix}$$

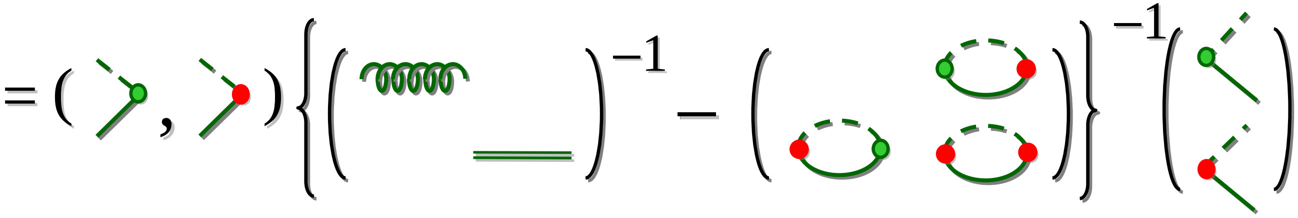
$\hat{D}$



Alternative expression for the full πρ scattering amplitude T

$$T = \frac{v_{WT} + v_{a_1}}{1 - (v_{WT} + v_{a_1})G} = (g_R, g)\left\{\begin{pmatrix} s-s_p & \\ & s-m_{a1}^2 \end{pmatrix} - \begin{pmatrix} & g_R G g \\ g G g_R & g G g \end{pmatrix}\right\}^{-1}\begin{pmatrix} g_R \\ g \end{pmatrix}$$

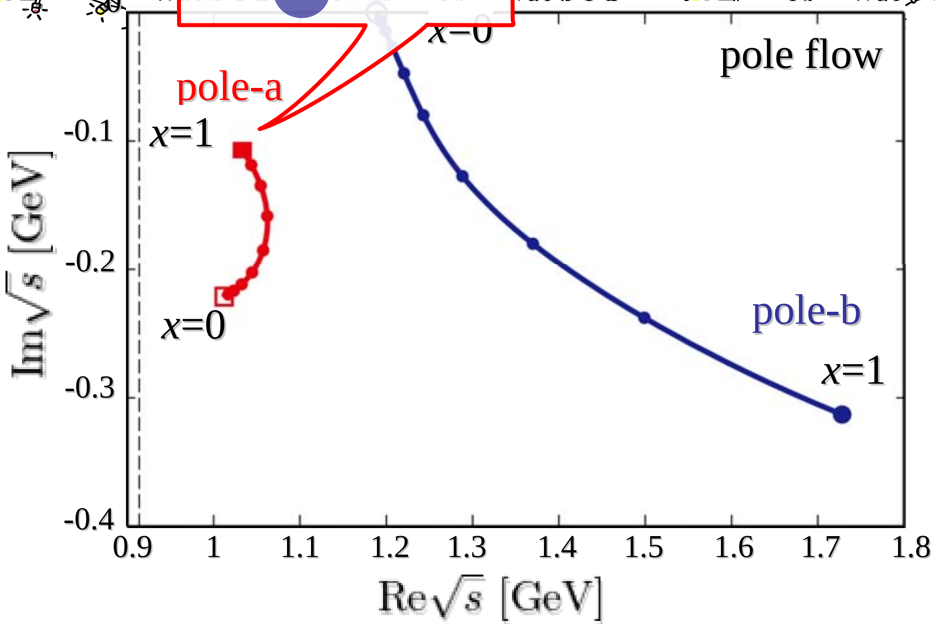
$\hat{D}$



$$D^{11} = \frac{z_a^{11}}{E - E_a} + \frac{z_b^{11}}{E - E_b} + \text{(regular)}$$

$$D^{22} = \frac{z_a^{22}}{E - E_a} + \frac{z_b^{22}}{E - E_b} + \text{(regular)}$$

Residues ~ probabilities of finding two a_1's in pole-a and -b

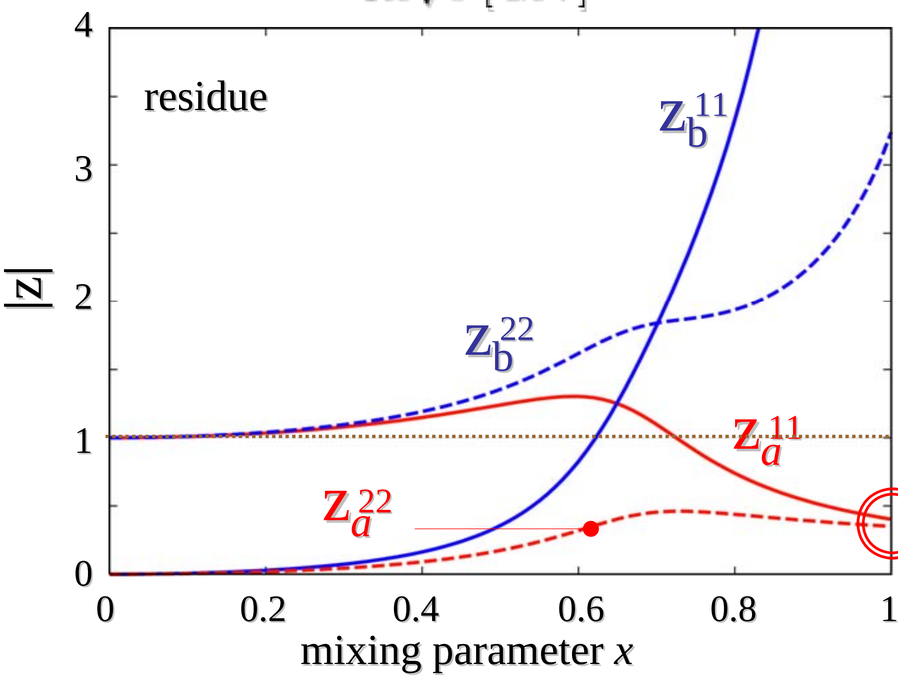


$$[\hat{D}_{\mathrm{full}}]^{11} = \frac{z_a^{11}}{E - E_a} + \frac{z_b^{11}}{E - E_b} + \text{(regular)}$$

$$[\hat{D}_{\mathrm{full}}]^{22} = \frac{z_a^{22}}{E - E_a} + \frac{z_b^{22}}{E - E_b} + \text{(regular)}$$

$$|a\rangle = \sqrt{z_a^{11}}|\quad\rangle + \sqrt{z_a^{22}}|\quad\rangle$$

$$|b\rangle = \sqrt{z_b^{11}}|\quad\rangle + \sqrt{z_b^{22}}|\quad\rangle$$



at physical point (x=1)

- pole-a has a component of the elementary a_1 meson ***comparable to*** that of composite a_1.

  (pole-a at x=1 is possibly observed one)

~

non-zero comp. of

Conclusions

» We discussed the mixing properties of $a_1(1260)$ meson as the superposition of the hadronic $\pi\rho$ composite and elementary a_1 based on the holographic QCD Lagrangian.

› bare a_1 … doesn't have molecule nature
› $\pi\rho$ molecule … "natural" regularization

Important to avoid the double-counting

» **We analyzed the pole nature by residues**

✓ **the pole expected to be observed is *pole-a*: having finite ● comp.**

✓ Non-trivial N_C dependence pole-nature ← **?** → large N_C

Future works

phenomenological interests

» τ-decay spectrum with our model parameter

[Wagner and Leupold, PRD78(08)053001, …]

» radiative decay width

[H. Nagahiro, L. Roca, A. Hosaka , E. Oset, PRD79(09)014015, …]

etc…

to see how the nature of poles affects ***observables***