Effect of 3π unitarity on resonance poles from heavy meson decays

Satoshi Nakamura

Excited Baryon Analysis Center (EBAC), JLab

EBAC Collaborators

Hiroyuki Kamano	(JLab)
Harry Lee	(ANL)
Toru Sato	(Osaka Univ.)

Introduction

Why we care 3π ($\pi\pi K$, etc.) scattering ?

Introduction

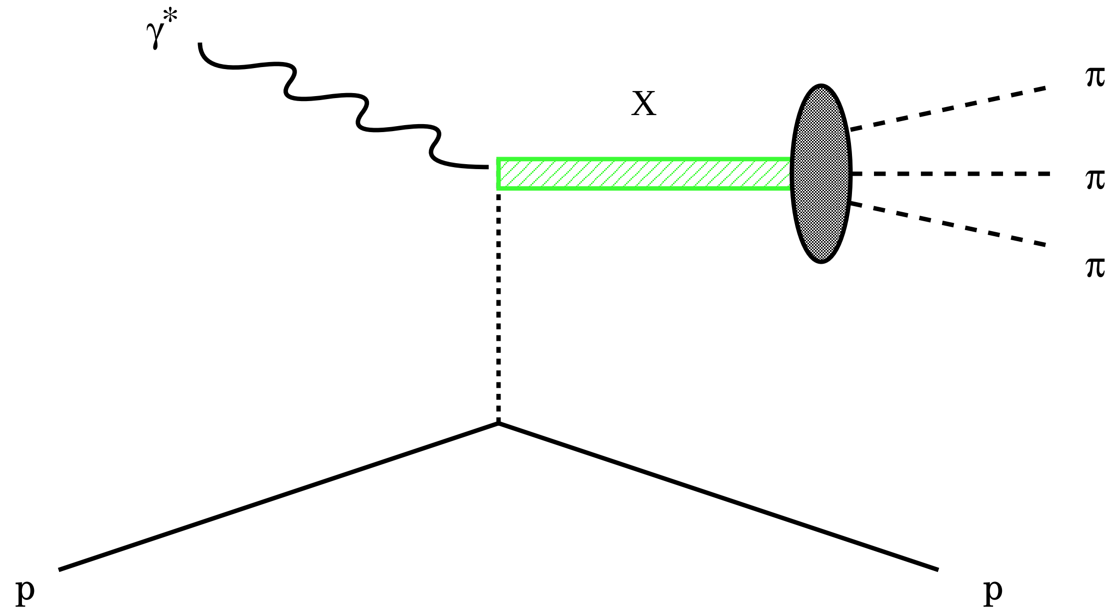
Why we care 3π ($\pi\pi K$, etc.) scattering ?

$\Longrightarrow$ Information of interesting physics is hidden in 3π from heavy meson decays

e.g.,

$*$	Exotic (hybrid) mesons (e.g.,$J^{PC} = 1^{-+}$)	BNL(E852),JLab(GlueX)
$*$	Light scalar mesons from D-decays	FNAL (E791, FOCUS),BABAR,CLEO
$*$	CP-violation from B-decays	BABAR, Belle

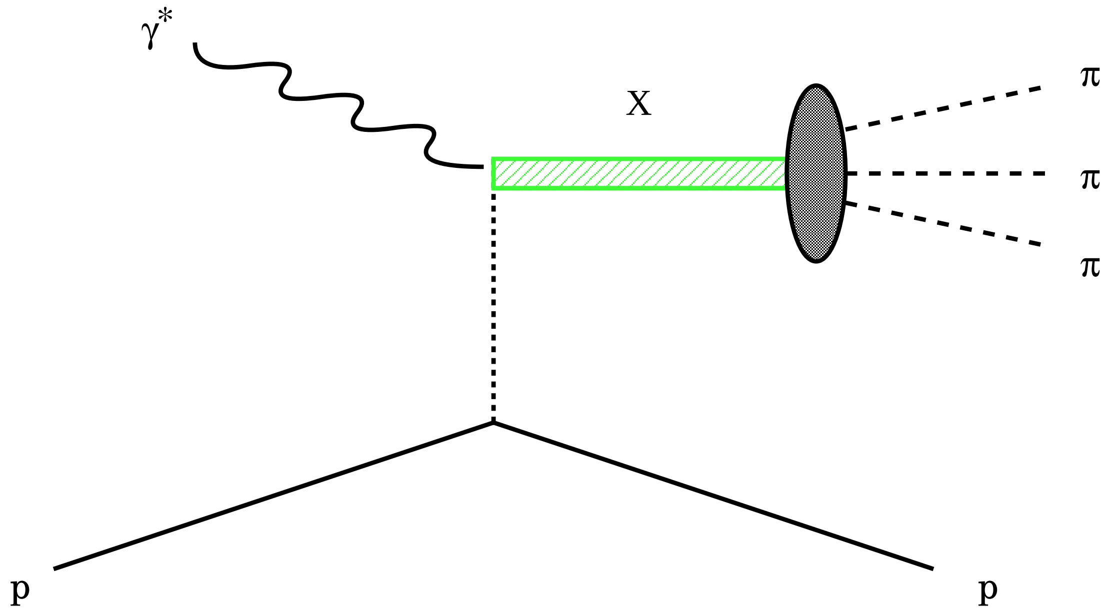
GlueX experiment (JLab, planned after 12 GeV upgrade)



New EBAC project : Analysis of 3π FSI in heavy meson decays

GlueX experiment

(JLab, planned after 12 GeV upgrade)

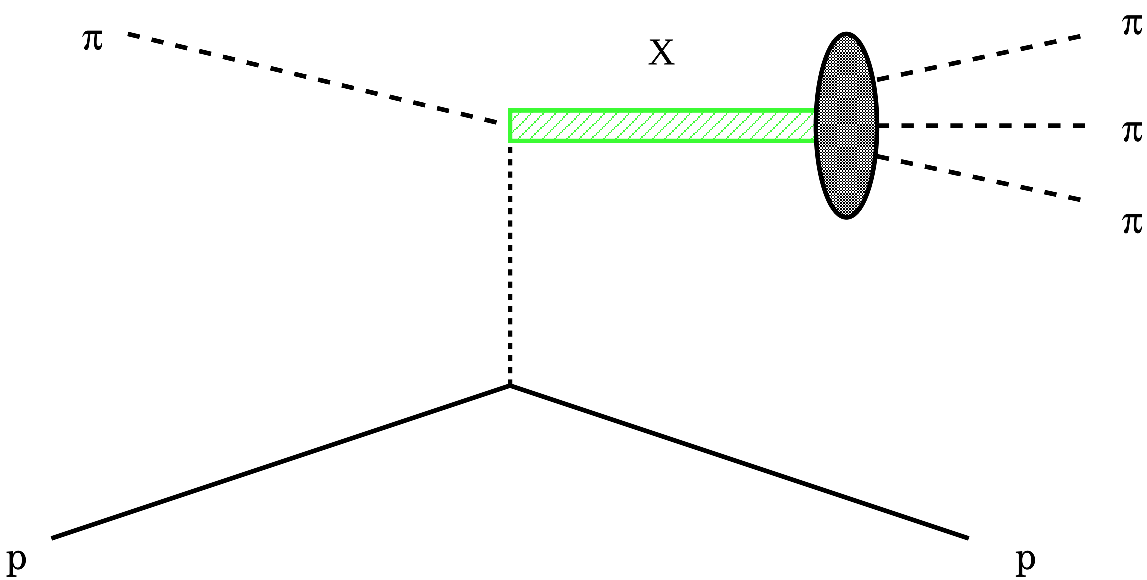


EBAC $\longrightarrow$ EHAC ?

(Excited Hadron Analysis Center)

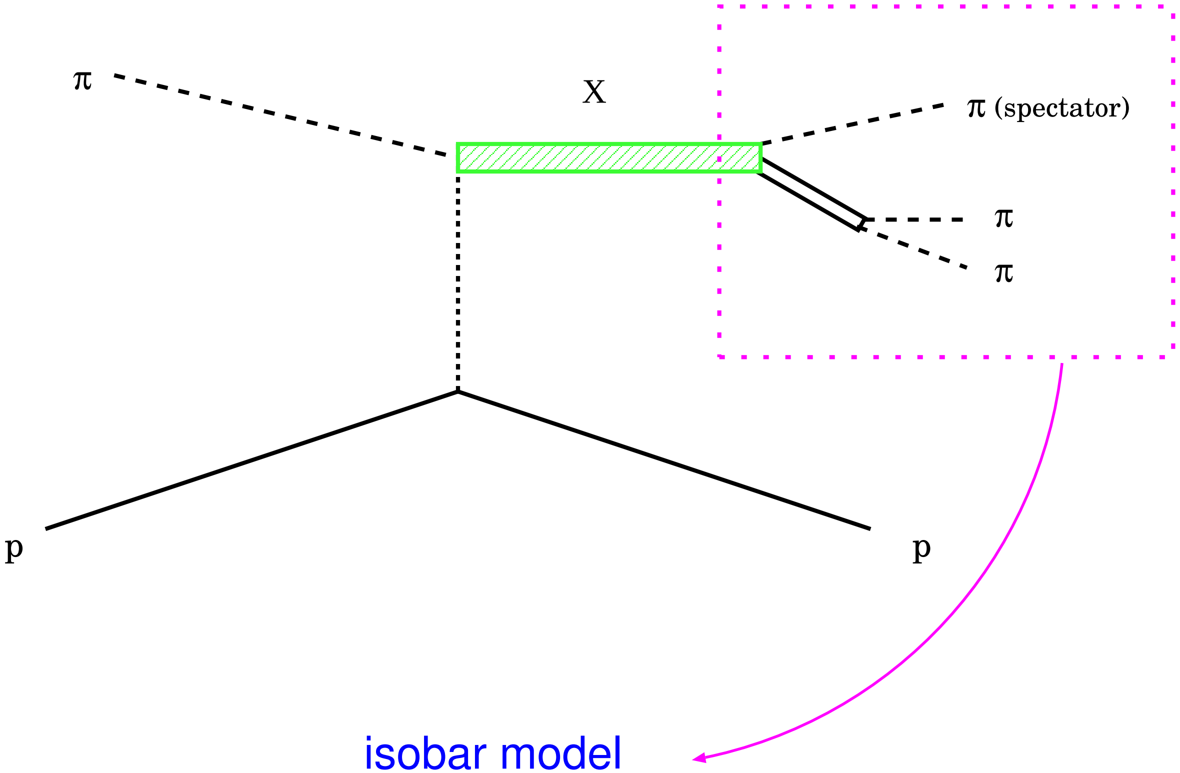
Previous analysis of 3π decay of X

E852 (BNL) $\pi^- p \to \pi^+ \pi^- \pi^- p$ Chung et al., PRD **65**, 072001 (2001)



Previous analysis of 3π decay of X

E852 (BNL) $\pi^- p \to \pi^+ \pi^- \pi^- p$ Chung et al., PRD **65**, 072001 (2001)



isobar model

∗ $\pi\pi$ subsystem forms a resonance

∗ 3rd π is a spectator

Our objective

(This work)

Examine the effect of 3π unitarity

$\Longrightarrow$ address the basic assumption of the isobar model

(Long term)

Comprehensive development of reliable 3π ($\pi\pi K$ etc.) model

Coupled-Channels Model

Matsuyama, Sato, Lee, Phys. Rept. **439**, 193 (2007)

$\underline{X \rightarrow (\pi M_a) \rightarrow \pi\pi\pi}$

Relevant channels (πM_a) : $\pi f_0(600)$, $\pi f_0(980)$, $\pi\rho(760)$, $\pi f_2(1270)$

M_a is a resonance found in $\pi\pi$ scattering

$\Longrightarrow$ First task is to develop $\pi\pi$ model

Simple $\pi\pi$ model

Coupled-channel scattering equation for $\pi\pi$ partial wave

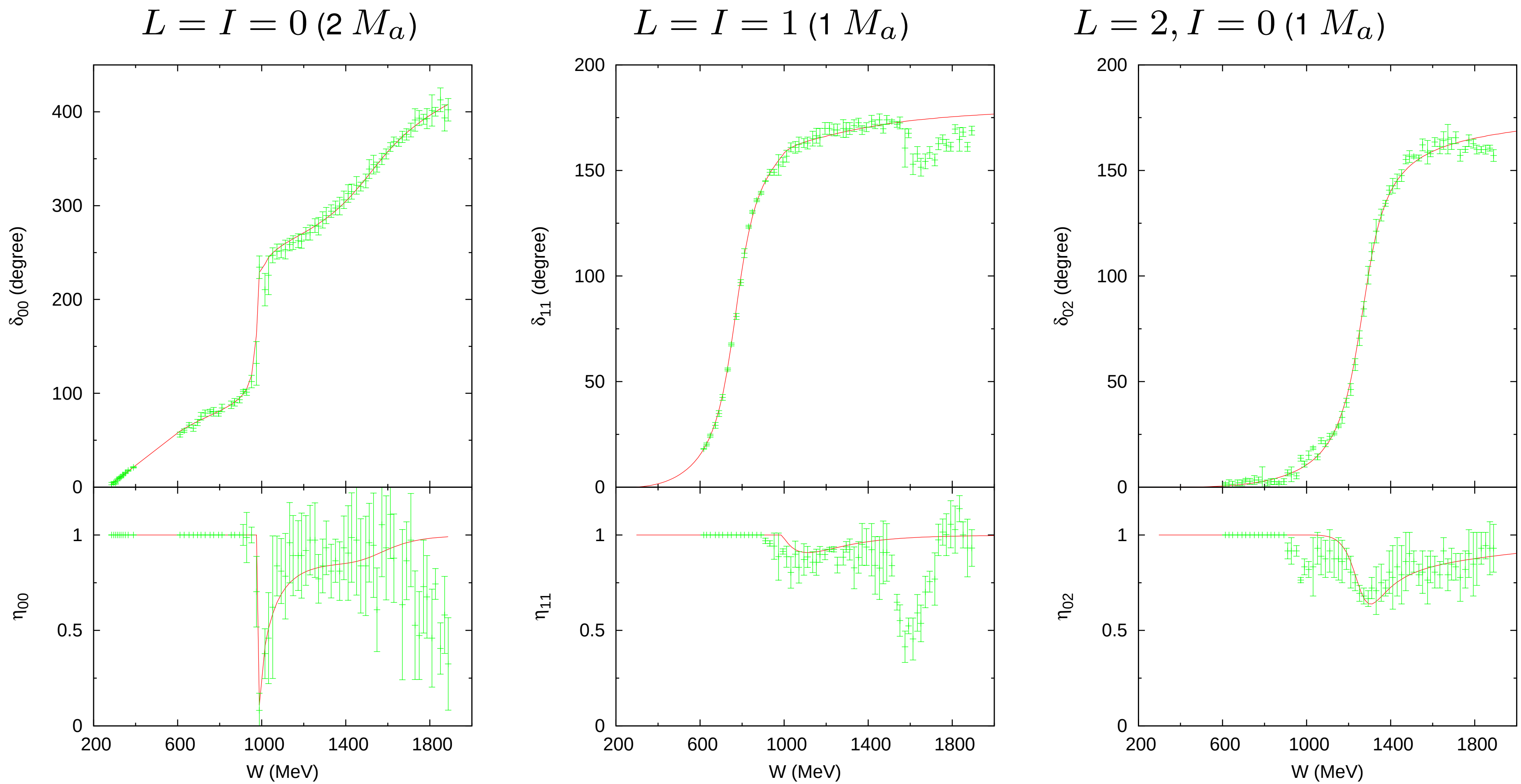
$$t_{i,j} = V_{i,j} + \sum_m \int_0^\infty q^2 dq V_{i,m}(k,q,W) \frac{1}{W - E_{1m}(q) - E_{2m}(q) + i\epsilon} t_{m,j}(q,k',W)$$

$$(i,j,m = \pi\pi, K\bar{K})$$

$$V_{i,j}(k,k',W) = \sum_a f_{M_a,i}(k) \frac{1}{W - m_{M_a}} f_{M_a,j}(k')$$

$$f_{M_a,i}(k) = \frac{g_{M_a,i}}{\sqrt{m_\pi}} \frac{1}{(1 + (c_{M_a,i}k)^2)} \left(\frac{k}{m_\pi}\right)^L$$

Phase and inelasticity of $\pi\pi$ amplitude

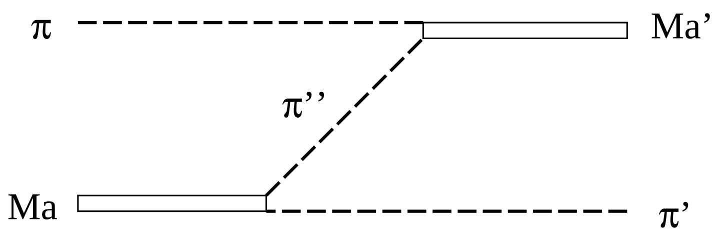


[Data: G. Gayer et al., NPB **75**, 189 (1974)]

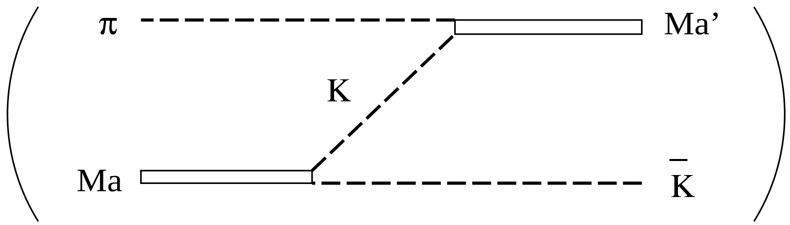
Pole positions in $\pi\pi$ amplitude

	Re[M_R] (MeV)		−Im[M_R] (MeV)	
	Ours	PDG	Ours	PDG
f_0 (600)	437	$400 - 1200$	256	$300 - 500$
f_0 (980)	897	980 ± 10	69	$20 - 50$
f_0 (1500)	1527	1505 ± 6	237	54.5 ± 3
ρ (760)	769	775.5 ± 0.3	81	74.5 ± 0.4
f_2 (1270)	1249	1275 ± 1.2	101	92.5 ± 1.3

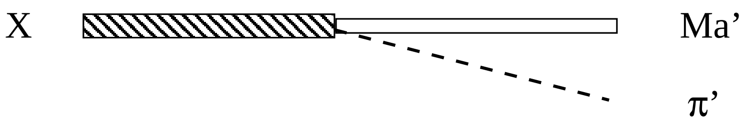
Quasi two-particle (πM_a) interaction



3 π Z-graph



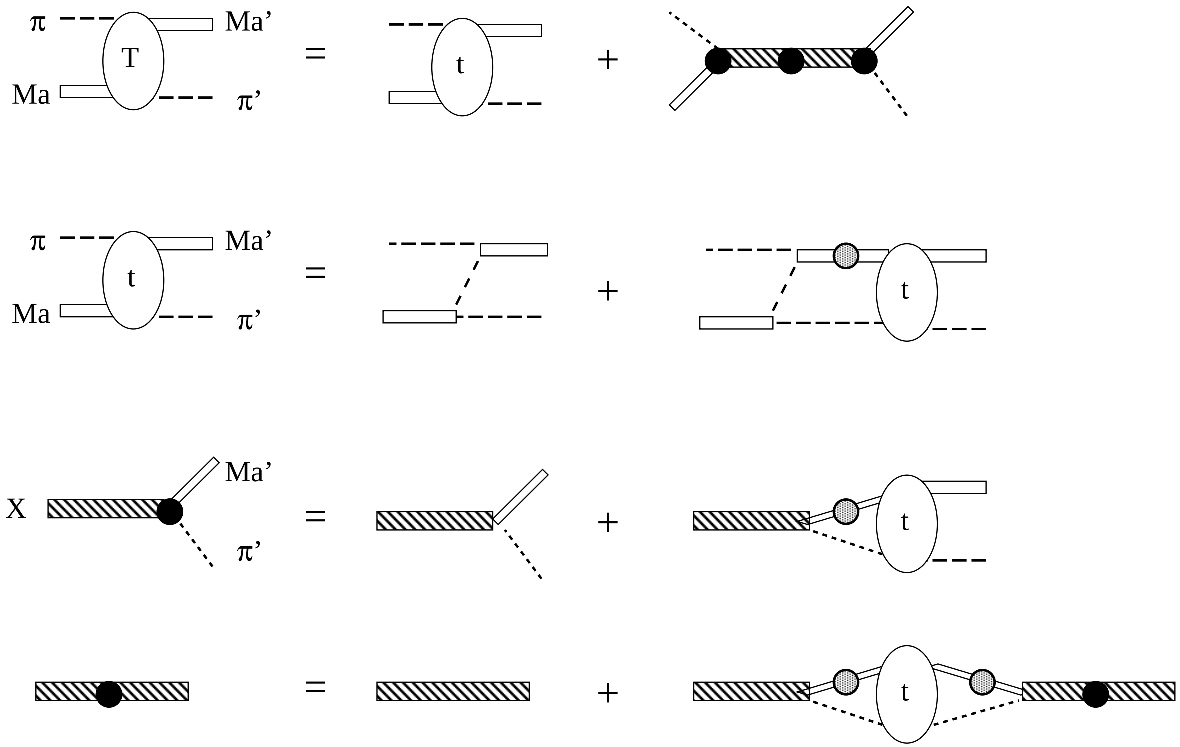
$\pi K \bar{K}$ Z-graph



X graph

Z-graphs play an essential role to maintain the unitarity !

Quasi two-particle (πM_a) scattering equation



Resonance pole : $W - M_X^0 - \Sigma_X(W) = 0$

Application

Effect of 3π Z-graph (unitarity) on $\pi_2(1670)$ pole

$\pi_2(1670)\ :\ J^{PC} = 2^{-+}$, $M_R = (1672 \pm 9.2) - (259 \pm 9)i$ MeV

Branching ratios

$\pi_2(1670)$	$\longrightarrow$	$\pi f_2(1270)$	56 %
	$\longrightarrow$	$\pi \rho(760)$	31 %
	$\longrightarrow$	$\pi f_0(600)$	11 %

Fit $M^0_{\pi_2}$, $\Gamma_{\pi_2 \to \pi M_a}$ to the pole and branching ratios for $\pi_2(1670)$

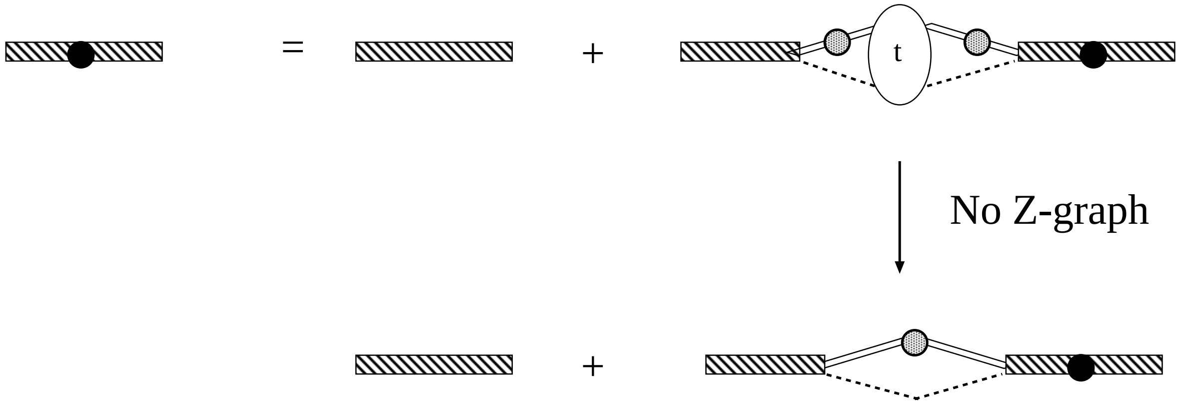
Pole search method : Suzuki, Sato, Lee, PRC **79**, 025205 (2009); ibid, **82**, 045206 (2010)

Branching ratio :

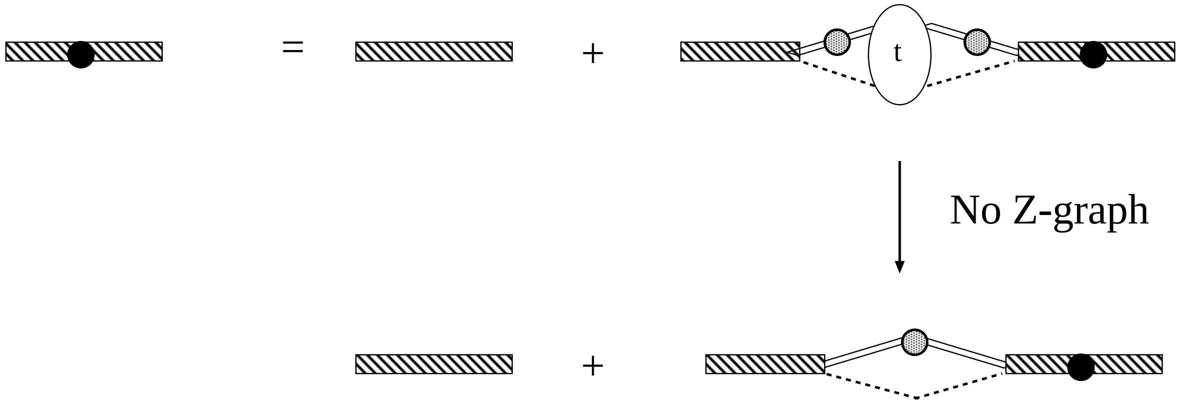
$$B(\pi_2(1670) \to \pi M_a) = \frac{\Gamma_{M_a}}{\Gamma_{\rm total}}$$

$$= \frac{\mathrm{Im}\left(\Gamma \frac{1}{W - E_\pi - E_{M_a} - \Sigma_{M_a}} \Gamma\right)}{\sum_{M'_a} \mathrm{Im}\left(\Gamma \frac{1}{W - E_\pi - E_{M'_a} - \Sigma_{M'_a}} \Gamma\right)}$$

Effect of 3π Z-graph on the π_2 pole position



Effect of 3π Z-graph on the π_2 pole position



w Z-graph $\quad M_R = 1672 - 259\, i$ MeV

w/o Z-graph $\quad M_R = 1670 - 257.6\, i$ MeV

- $\ast$ The effect of 3π Z-graph is very small
- $\ast$ $\pi K \bar{K}$ Z-graph could have a significant effect
- $\ast$ Effect could be seen more clearly in Dalitz plot

Summary

3π ($\pi\pi K$) from heavy meson decay contains information of interesting physics !

exotic (hybrid) meson, light scalar mesons, CP violation

EBAC ($\longrightarrow$ EHAC?) steps toward developing reliable 3π model !

Model

Coupled-channels quasi two-body (πM_a) scattering equation

* $\pi\pi$ model
* 3π Z-graph, $\pi K\bar{K}$ Z-graph (essential for unitarity)
* bare resonance mechanism

Effect of 3π unitarity on resonance pole

- Simple model
- π_2 (1670), $J^{PC} = 2^{-+}$; pole and branching ratio are fitted
- Shift of the pole due to 3π Z-graph is very small

Near future

- Inclusion of $\pi K \bar{K}$ Z-graph
- Dalitz plot analysis of $D \to \pi\pi\pi \; (\pi\pi K)$

  $\Rightarrow$ Effect of 3π unitarity on scalar resonances extracted from the analysis
- $\pi\pi$ (πK, etc.) interaction based on chiral Lagrangian