Signature of strange dibaryon in kaon-induced reaction

Shota Ohnishi [A]

in collaboration with; Y. Ikeda[B], H. Kamano[C], T. Sato[A]

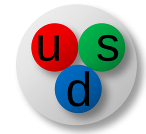
A; Department of Physics, Osaka University
B; Department of Physics, Tokyo Institute of Technology
C; Department of Physics, Osaka City University

Contents

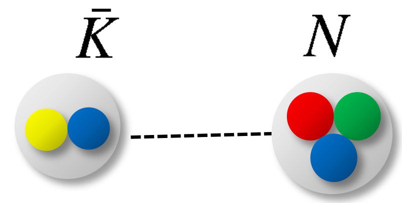
- ***Introduction***
- *Three-body Scattering Equation*
- *Model of 2-body Interaction*
- *Results*
- *Conclusion*

$\Lambda(1405)$ J$^{\pi}$=1/2^{-}, $S = -1$

◆ q^3(usd): P-wave excited state



◆ $\bar{K}N$ unstable bound state



- *Dalitz, Wong, Tajasekaran, PR 153(1967)1617*
- Chiral unitary approach: two resonances

  Jido, Oller, Oset, Ramos Meissner, NPA 725(2003)263

⇨ strongly attractive $\bar{K}N$ interaction in *I=0, L=0*

⇨ deeply bound kaonic nuclei are proposed

Yamazaki, Akaishi, PLB535, 70(2002)

strange dibaryon $\bar{K}NN - \pi\Sigma N$

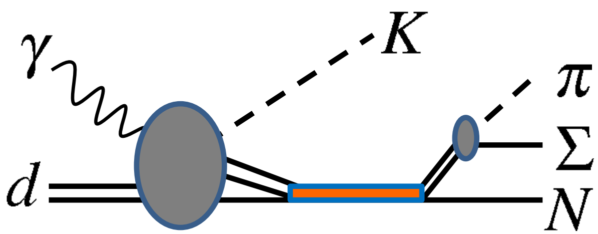
- simplest deeply bound kaonic nuclei
- many particle dynamics can be examined accurately

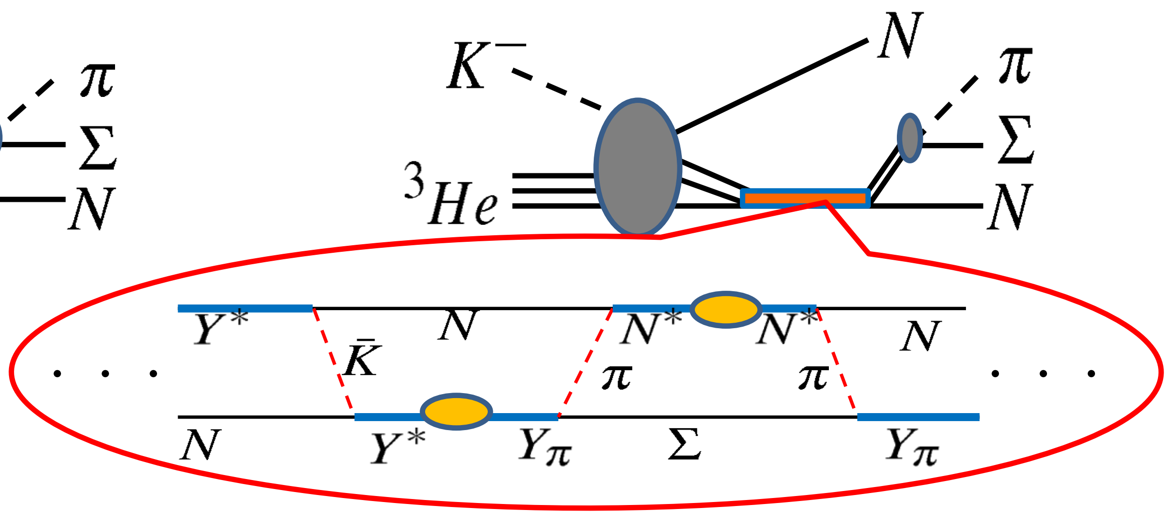
theoretical analyses:

	phenomenological	Chiral SU(3)
Faddeev	*Shevchenko, Gal , Mares*	*Ikeda, Sato*
Variational	*Akaishi, Yamazaki* *Wycech, Green*	*Doté, Hyodo, Weise*

strange dibaryon

- signal of strange dibaryon resonance from reactions





Optical potential approach : *Koike, Harada, PRC80, 055208(2009)*

Purpose of this work : within Faddeev approach

– study 3-body scattering amplitude

– examine signal of strange dibaryon resonances

– examine dynamics of $\bar{K}N - \pi\Sigma$ in resonance production reaction

- *Introduction*
- ***Three-body Scattering Equation***
- *Model of 2-body Interaction*
- *Results*
- *Conclusion*

Coupled channel equation for $\bar{K}NN-\pi\Sigma N$

Faddeev eq. $$T_i(W) = t_i(W-E_i) + \sum_{j\neq i} t_i(W-E_i)G_0(W)T_j(W)$$

separable 2-body Interaction ; $V(\mathbf{q}',\mathbf{q}) = \lambda g(\mathbf{q}')g(\mathbf{q})$

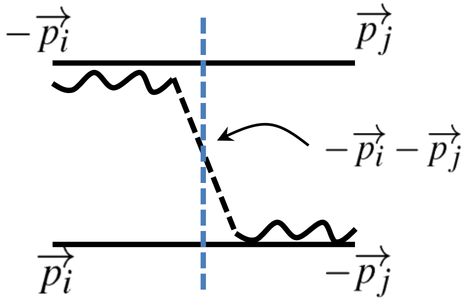
Alt-Grassberger-Sandhas(AGS) eq. : *Xij* ; 3-body amplitude

$$\begin{aligned} X_{i,j}(\mathbf{p}_i,\mathbf{p}_j,W) &= (1-\delta_{i,j})Z_{i,j}(\mathbf{p}_i,\mathbf{p}_j,W) \\ &+ \sum_{n\neq i}\int d\mathbf{p}_n Z_{i,n}(\mathbf{p}_i,\mathbf{p}_n,W)\tau_n(W-E_n)X_{n,j}(\mathbf{p}_n,\mathbf{p}_j,W) \end{aligned}$$

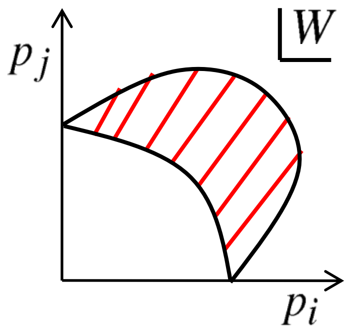
$$Z_{i,j}(\mathbf{p}_i,\mathbf{p}_j,W) = 2\pi\int_{-1}^{1} d(\hat{\mathbf{p}}_i\cdot\hat{\mathbf{p}}_j)\frac{g(q_i)g(q_j)}{W-E_i(p_i)-E_j(p_j)-E_k(\mathbf{p}_i+\mathbf{p}_j)}$$

Singularity of particle exchange interaction

$$Z_{i,j}(\mathbf{p}_i,\mathbf{p}_j,W) = 2\pi\int_{-1}^{1} d(\hat{\mathbf{p}}_i\cdot\hat{\mathbf{p}}_j)\frac{g(q_i)g(q_j)}{W-E_i(p_i)-E_j(p_j)-E_k(\mathbf{p}_i+\mathbf{p}_j)+i\varepsilon}$$



Z-diagram



moon shape singularity

methods to handle moon shape singularity numerically

⇨ spline interpolation, point method

Point method

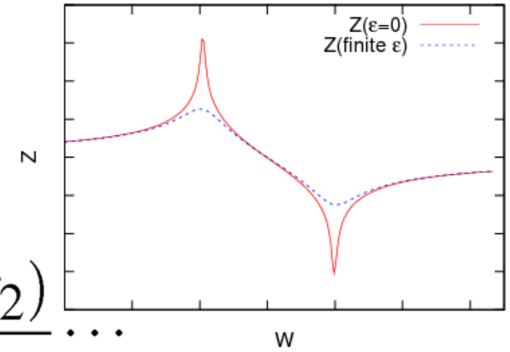
L. Schlessinger, PR 167, 1411(1968)

Kamada, Koike, Glökle, TP 109 (2003), 869.

$$X(E+i\varepsilon) = \frac{X(E+i\varepsilon_1)}{1+\frac{a_1(\varepsilon-\varepsilon_1)}{1+\cdots}}$$

$$= \frac{X(E+i\varepsilon_1)}{1+}\frac{a_1(\varepsilon-\varepsilon_1)}{1+}\frac{a_2(\varepsilon-\varepsilon_2)}{1+}\cdots$$

$$a_l = \frac{1}{\varepsilon_l-\varepsilon_{l+1}}\left[1+\frac{a_{l-1}(\varepsilon_{l+l}-\varepsilon_{l-1})}{1+}\frac{a_{l-2}(\varepsilon_{l+1}-\varepsilon_{l-1})}{1+}\cdots + \frac{a_1(\varepsilon_{l+1}-\varepsilon_1)}{1-[X(E+i\varepsilon_1)/X(E+i\varepsilon_{l+1})]}\right]$$



evaluate X at finite ε_i

continued fraction

Extrapolate X at ε=0

- *Introduction*
- *Three-body Scattering Equation*
- ***Model of 2-body Interaction***
- *Results*
- *Conclusion*

$\bar{K}N-\pi\Sigma$ Interaction

meson-baryon interaction based on WT Lagrangian

$$L_I = \frac{i}{8F_\pi^2} Tr(\bar{\psi}_B \gamma^\mu [[\phi, \partial_\mu \phi], \psi_B])$$

"energy-independent" potentials (static approximation $q \to 0$)

$$V_{\alpha\beta}(q',q) = -\lambda_{\alpha\beta} \frac{1}{32\pi^2 F_\pi^2} \frac{m_\alpha + m_\beta}{\sqrt{\omega_\alpha(q')\omega_\beta(q)}} \left(\frac{\Lambda_\alpha^2}{q'^2+\Lambda_\alpha^2}\right)\left(\frac{\Lambda_\beta^2}{q^2+\Lambda_\beta^2}\right)$$

"energy-dependent" potentials (chiral unitary)

$$V_{\alpha\beta}(q',q;E) = -\lambda_{\alpha\beta} \frac{1}{32\pi^2 F_\pi^2} \frac{2E - M_\alpha - M_\beta}{\sqrt{\omega_\alpha(q')\omega_\beta(q)}} \left(\frac{\Lambda_\alpha^2}{q'^2+\Lambda_\alpha^2}\right)\left(\frac{\Lambda_\beta^2}{q^2+\Lambda_\beta^2}\right)$$

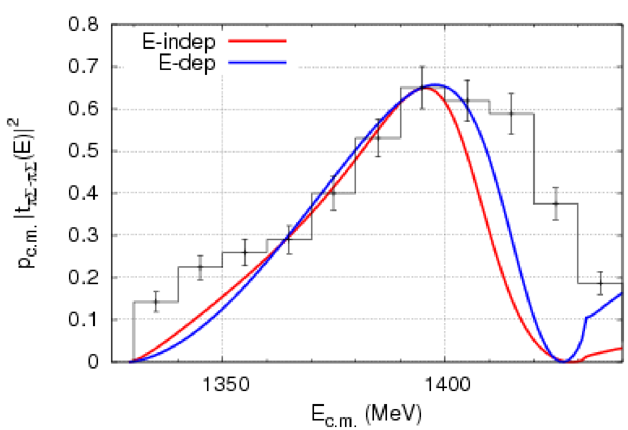
E; two body scattering energy

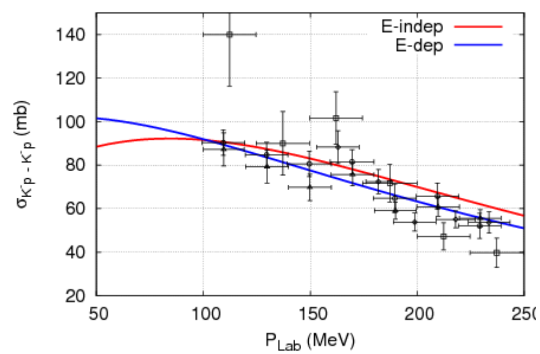
$$\lambda_{\beta\alpha}^{I=0} = \begin{array}{c} \\ \bar{K}N \\ \pi\Sigma \end{array} \begin{array}{c} \begin{array}{cc} \bar{K}N & \pi\Sigma \end{array} \\ \begin{pmatrix} 6 & -\sqrt{6} \\ -\sqrt{6} & 8 \end{pmatrix} \end{array} \qquad \lambda_{\beta\alpha}^{I=1} = \begin{array}{c} \\ \bar{K}N \\ \pi\Sigma \end{array} \begin{array}{c} \begin{array}{cc} \bar{K}N & \pi\Sigma \end{array} \\ \begin{pmatrix} 2 & -2 \\ -2 & 4 \end{pmatrix} \end{array}$$

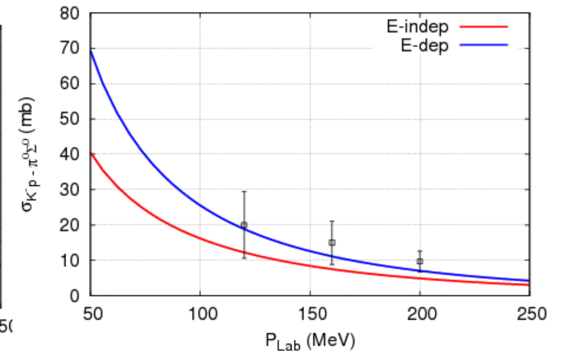
cutoff (model parameters)

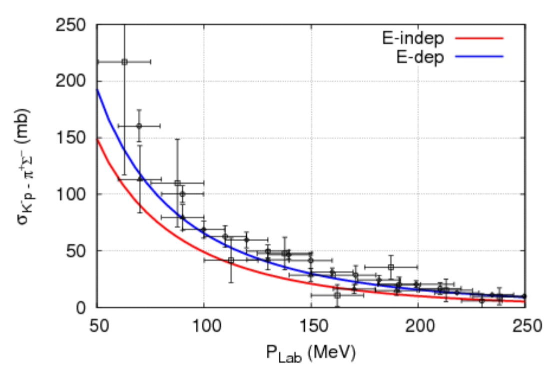
	$\Lambda^{I=0}_{\bar{K}N}$(MeV)	$\Lambda^{I=0}_{\pi\Sigma}$(MeV)	$\Lambda^{I=1}_{\bar{K}N}$(MeV)	$\Lambda^{I=1}_{\pi\Sigma}$(MeV)
E-indep.	1000	700	920	960
E-dep.	1000	700	725	725

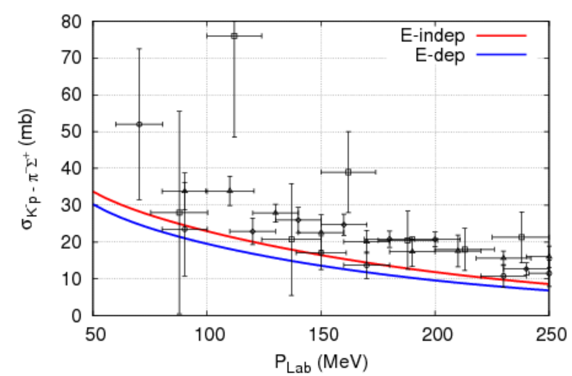
cutoff which reproduce invariant mass $I=0\ \pi\Sigma$ & 2-body cross sections.



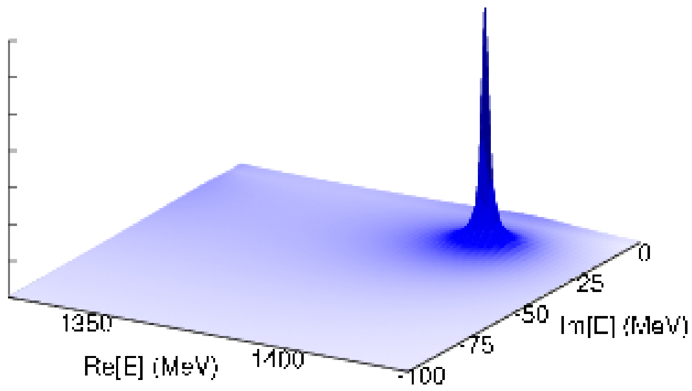




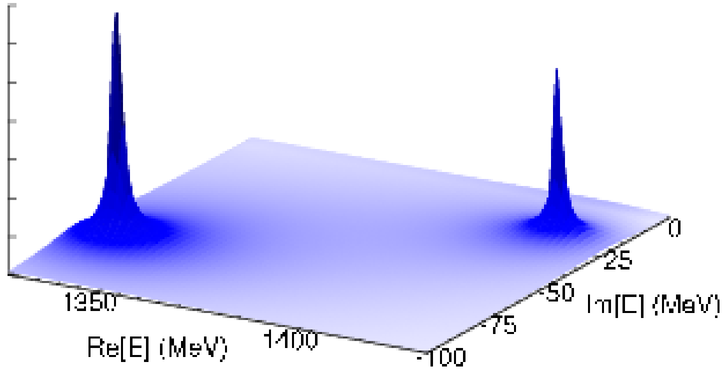




pole positions of two-body amplitude



E-indep.; only one pole



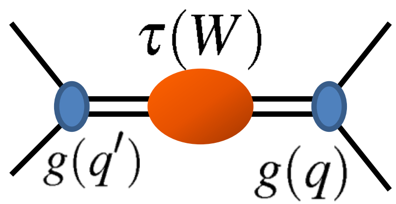
E-dep.; two poles
~ chiral unitary model

Possibility to distinguish two models
from strange dibaryon production reaction

Model of $\bar{K}NN - \pi\Sigma N$ system

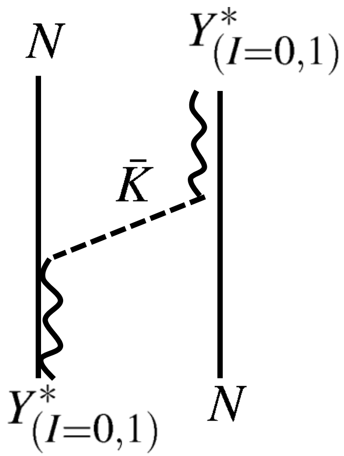
2-body meson-baryon interaction; $J^{\pi} = 1/2^{-}$

$t(\mathbf{q}', \mathbf{q}; W) =$



$$\overbrace{\begin{pmatrix} \bar{K} \\ N \end{pmatrix} \begin{pmatrix} \pi \\ \Sigma \end{pmatrix}}^{S=-1}_{I=0,1}$$

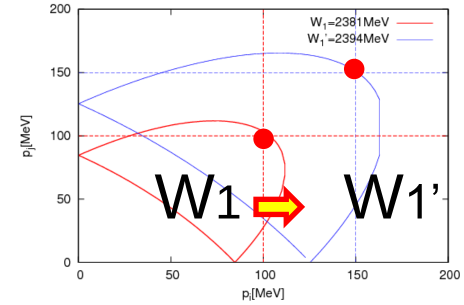
3-body particle exchange (Z) interaction

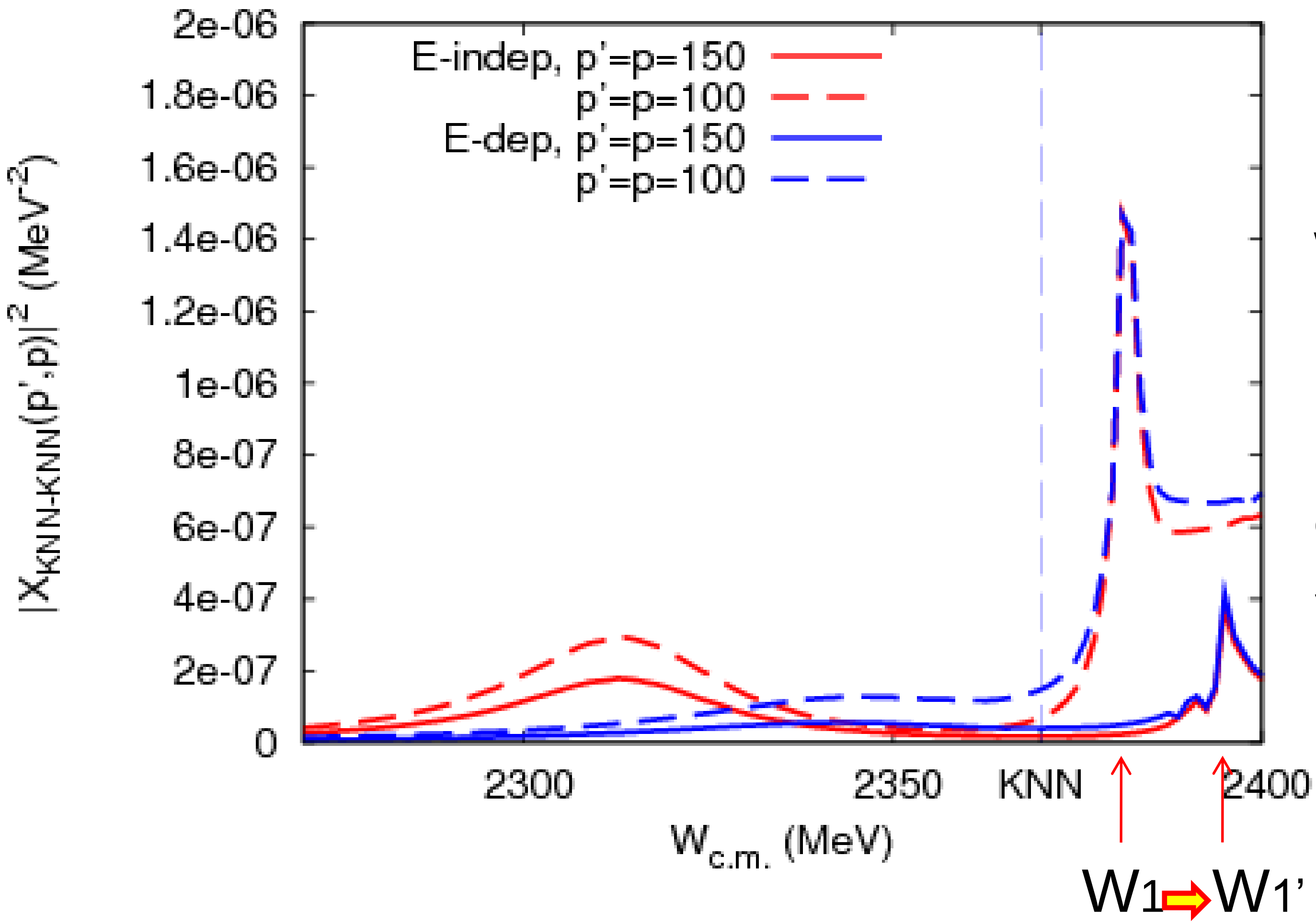


report on our first results on only meson-baryon S=-1 interaction, only kaon exchange Z.

- *Introduction*
- *Three-body Scattering Equation*
- *Model of 2-body Interaction*
- ***Results***
- *Conclusion*

$|X(W,p',p)|^2$ $\quad X_{\bar{K}NN,\bar{K}NN}$

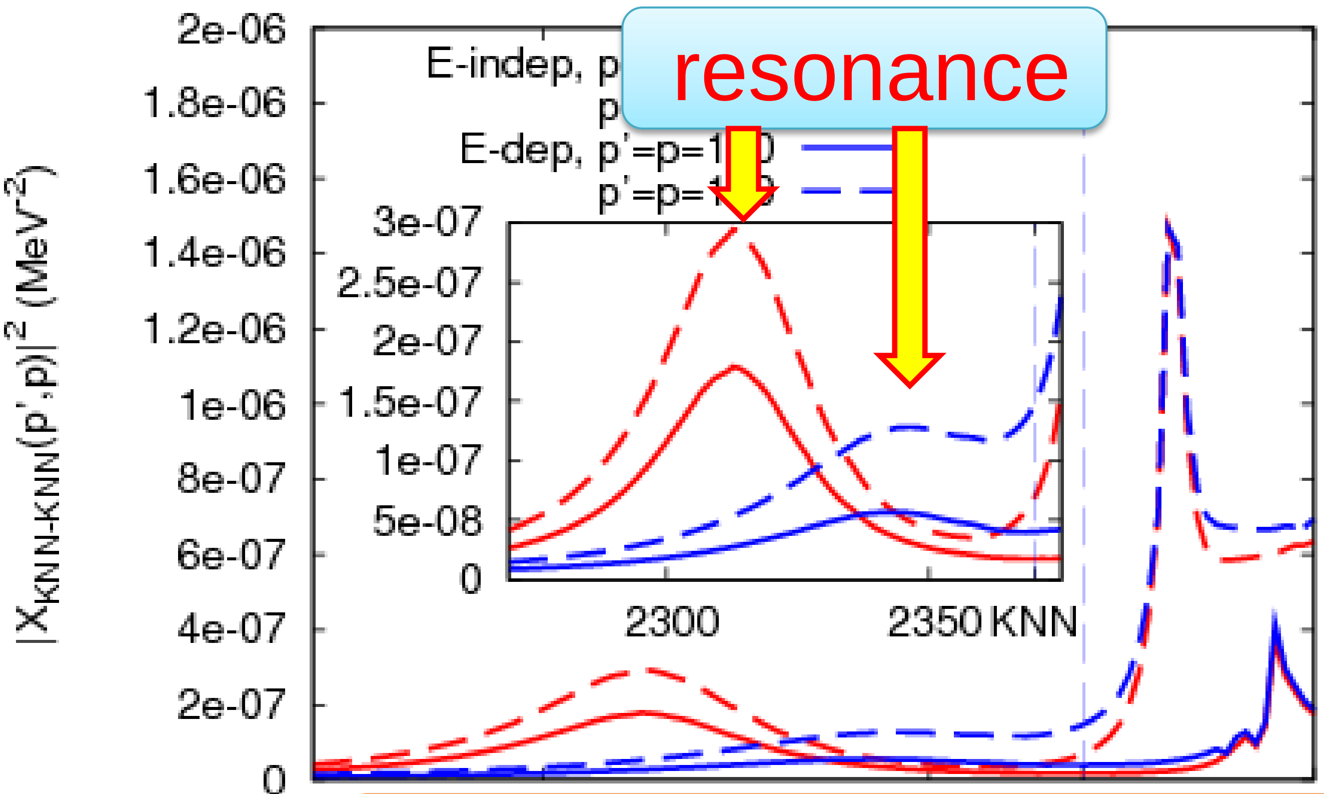


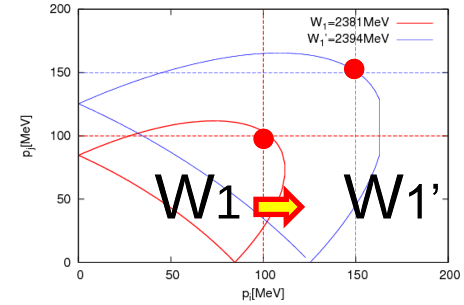


W1 depend on momentum.

correspond to moon shape singularity

$|X(W,p',p)|^2$





W1 depend on momentum.

correspond to moon shape singularity

Three-body amplitudes depend on two-body potential models.

- *Introduction*
- *Three-body Scattering Equation*
- *Model of 2-body Interaction*
- *Results*
- ***Conclusion***

Conclusion

- Signal of dibaryon resonance shows up in the three-body amplitude *X*.
- Strange dibaryon production reaction can be used to distinguish dynamical model of Λ(1405).

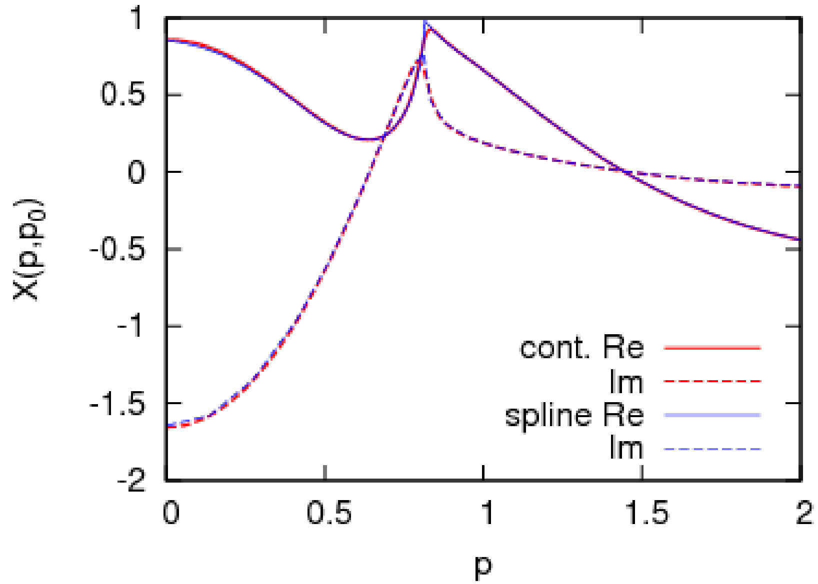
Future plan

- Include complete 3-body dynamics (include N and π exchange Z)
- Study $X_{\pi\Sigma N-\bar{K}NN}$, etc.

Thank you!

test of approximation method

three identical bosons model of Amado
scattering of a boson *b* from a two-boson bound state *d*



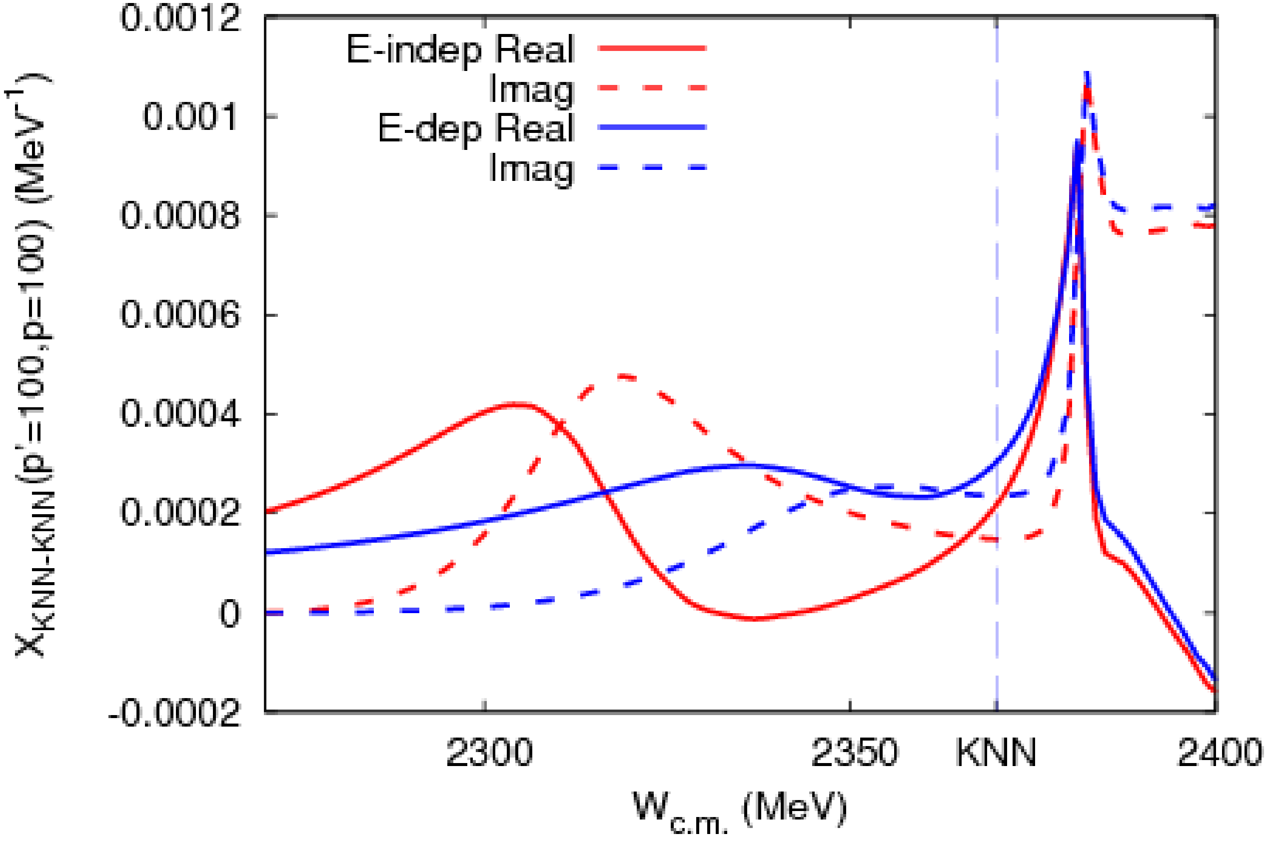
Matsuyama, Sato, Lee, PR439, 193(2003)

$$\hbar = 2m = 1, E = 1, B = 1.5, \beta = 5$$

m; boson mass, E; total energy,
B; two-body binding energy, β; cut-off

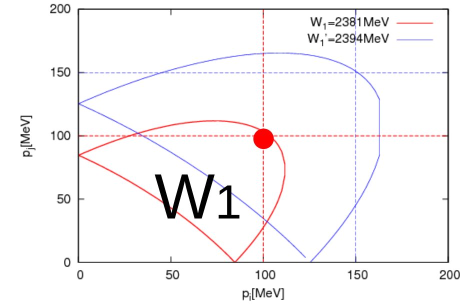
⇨ We can use this method for $\bar{K}NN - \pi\Sigma N$ coupled-channel AGS eq.

model dependence of X

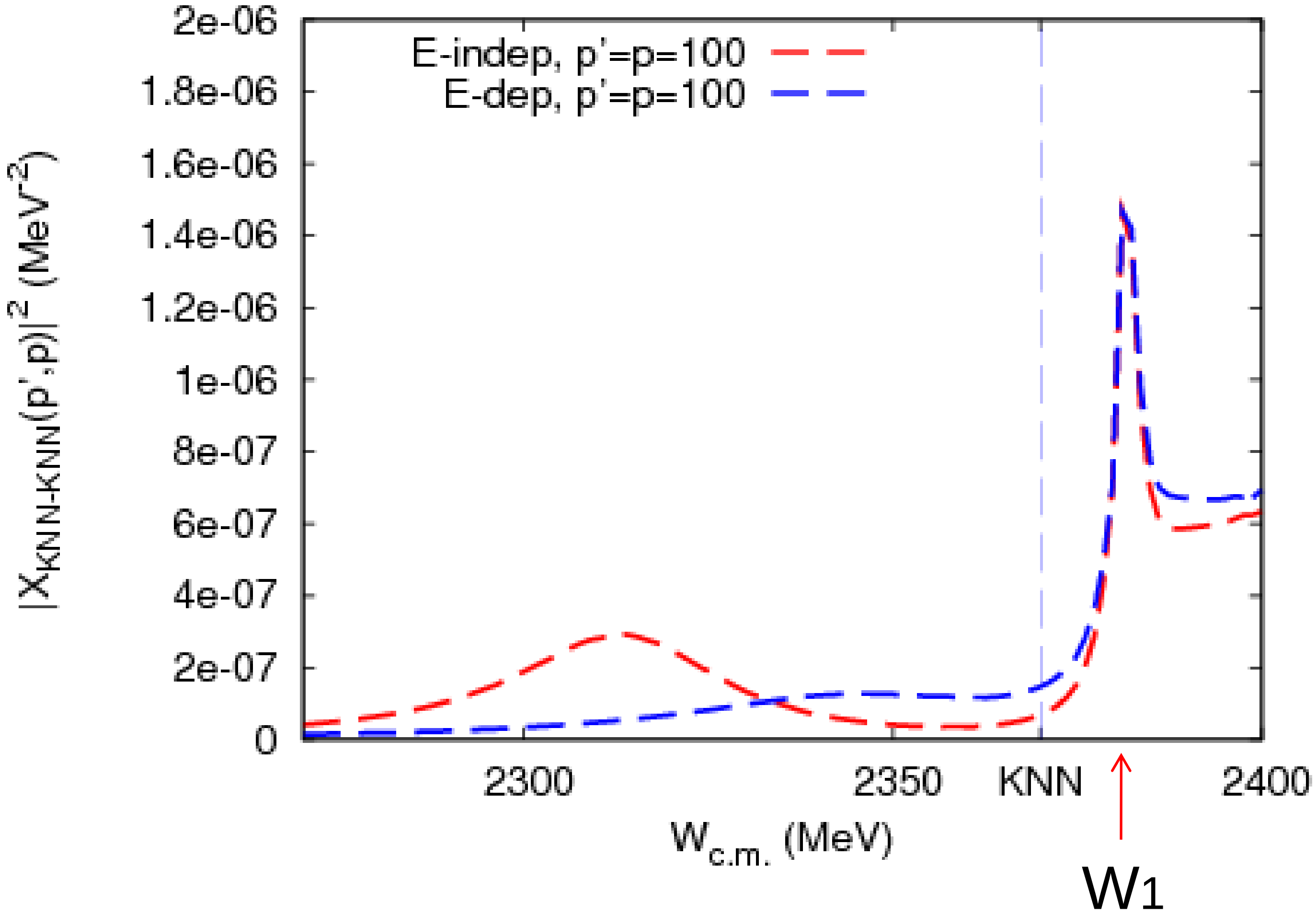


Three-body amplitudes depend on two-body potential models.

$|X(W,p',p)|^2$



200
150
100
50
0
0
50
100
150
200
W1=2381MeV
W1'=2394MeV
p_j[MeV]
p_i[MeV]
W1



E-indep, p'=p=100
E-dep, p'=p=100
2e-06
1.8e-06
1.6e-06
1.4e-06
1.2e-06
1e-06
8e-07
6e-07
4e-07
2e-07
0
2300
2350
KNN
2400
W1
$W_{c.m.}$ (MeV)
$|X_{KNN-KNN}(p',p)|^2$ (MeV^{-2})