$K^{bar}N$ and $\pi\Sigma$ Amplitudes in One-Hadron-Exchange Potential Model

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(Hyp-X @ Tokai.Ibaraki 090914-18)

Our Model of BB and MB potentials

- The One-Hadron-Exchange mechanism
- The SU(3)-symmetric coupling constants
- Mesons and Baryons with Physical Masses and Widths
- Gaussian Source Functions (Form Factors)

Our BB potentials describe interactions between all octet baryon pairs(**From NN to ΞΞ**)

Funabashi-Gifu Potential

GSOBEP

As an extension of our BB potential model, we propose meson-baryon(MB) potentials:

All parameters (coupling constants, etc) determined in BB potentials are fixed in MB potentials.

Meson-Baryon Potentials

Mesons : Pseudoscalar Mesons
Baryons : Octet Baryons

S= 1 sector: **KN**

S= 0 sector: **πN – ηN – KΛ – KΣ**

S= -1 sector: **πΛ –πΣ – $\bar{K}$N – ηΛ – ηΣ**

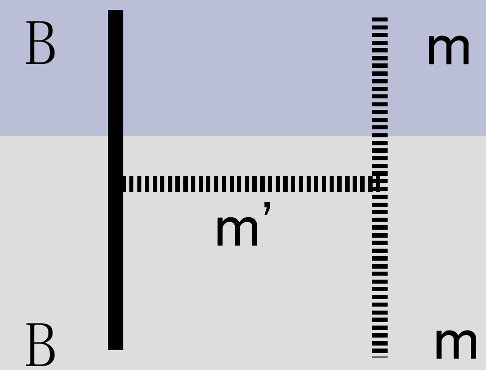
S= -2 sector: **πΞ – ηΞ – $\bar{K}$Λ – $\bar{K}$Σ**

S= -3 sector: **$\bar{K}$Ξ**

Interaction Mechanisms

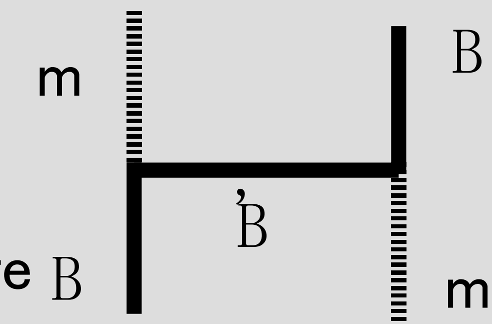
Meson–Exchange Diagrams

Vector–Meson–Exchange
Scalar–Meson–Exchange



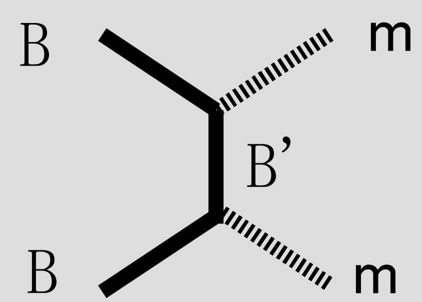
Baryon–Exchange Diagrams

Octet–Baryon Exchange
Baryon–Resonance–Exchange



Baryon–Pole Diagrams

Octet–Baryon Pole
Baryon–Resonance–Pole



Baryon–Pole Diagrams give Separable Potentials

SU(3) model for Baryons and Mesons

1. Octet baryons in the SU(3) model:

$$\Psi_8^B = \begin{bmatrix} \Sigma^0/\sqrt{2} + \Lambda/\sqrt{6} & \Sigma^+ & p \\ \Sigma^- & -\Sigma^0/\sqrt{2} + \Lambda/\sqrt{6} & n \\ \Xi^- & \Xi^0 & -\sqrt{\frac{2}{3}}\Lambda \end{bmatrix}$$

2. Octet pseudoscalar mesons in the SU(3) model:

$$\Phi_8^P = \begin{bmatrix} \pi^0/\sqrt{2} + \eta_8/\sqrt{6} & \pi^+ & K^+ \\ \pi^- & -\pi^0/\sqrt{2} + \eta_8/\sqrt{6} & K^0 \\ K^- & \bar{K}^0 & -\sqrt{\frac{2}{3}}\eta_8 \end{bmatrix}$$

3. Octet scalar mesons in the SU(3) model:

$$\Phi_8^S = \begin{bmatrix} a^0/\sqrt{2} + f_0/\sqrt{6} & a^+ & \kappa^+ \\ a^- & -a^0/\sqrt{2} + f_0/\sqrt{6} & \kappa^0 \\ \kappa^- & \bar{\kappa}^0 & -\sqrt{\frac{2}{3}}f_0 \end{bmatrix}$$

4. Octet vector mesons in the SU(3) model:

$$\Phi_8^V = \begin{bmatrix} \rho^0/\sqrt{2} + \phi/\sqrt{6} & \rho^+ & K^{*+} \\ \rho^- & -\rho^0/\sqrt{2} + \phi/\sqrt{6} & K^{*0} \\ K^{*-} & \bar{K}^{*0} & -\sqrt{\frac{2}{3}}\phi \end{bmatrix}$$

5. Singlet mesons:

$$\Phi_1^P = \eta', \qquad \Phi_1^S = \sigma, \qquad \Phi_1^V = \omega$$

Interaction Lagrangians in the SU(3) model

Definitions of baryon-baryon-meson coupling constants:

$$\mathcal{L}_{BBm} = g^{(8)}_{m1}\,\mathrm{Tr}[\bar{\Psi}^B_8 \Phi^m_8 \Psi^B_8] + g^{(8)}_{m2}\,\mathrm{Tr}[\bar{\Psi}^B_8 \Psi^B_8 \Phi^m_8] + g^{(1)}_{m}\,\mathrm{Tr}[\bar{\Psi}^B_8 \Psi^B_8]\Phi^m_1]$$

where, $m = P, S, V$.

Definition of meson-meson-meson coupling constants:

$$\begin{aligned}\mathcal{L}_{PPm} = \; & g^{(888)}_{PPm1}\,\mathrm{Tr}[(\Phi^P_8)^\dagger \Phi^P_8 \Phi^m_8] + g^{(888)}_{PPm2}\,\mathrm{Tr}[(\Phi^P_8)^\dagger \Phi^m_8 \Phi^P_8] + g^{(881)}_{PPm}\,\mathrm{Tr}[(\Phi^P_8)^\dagger \Phi^P_8]\Phi^m_1] \\ + \; & g^{(818)}_{PPm}\,\mathrm{Tr}[(\Phi^P_8)^\dagger \Phi^m_8]\Phi^P_1] + g^{(188)}_{PPm}(\Phi^P_1)^\dagger \mathrm{Tr}[\Phi^P_8 \Phi^m_8] + g^{(111)}_{PPm}(\Phi^P_1)^\dagger \Phi^P_1 \Phi^m_1\end{aligned}$$

where, $m = S, V$.

Symmetric(α=0) for PPS **α=F/(F+D)**

Antisymmetric(α=1) for PPV

Forms of Three-Meson Coupling

ps meson–ps meson–vector meson coupling

$$L = g_{ppv}\phi_v^\mu \phi_p \partial_\mu \phi_p$$

ps meson–ps meson–scalar meson coupling

$$L = g_{pps} m_\pi \phi_s \phi_p \phi_p$$

or

$$L = -\frac{g_{pps}}{m_\pi}\phi_s \partial_\mu \phi_p \partial^\mu \phi_p$$

The latter $\longleftarrow$ Low-energy theorem (Soft pion limit)

Contributions for πN and KN potentials

πN : σ-ex, f_0-ex

ρ-ex

N-ex, Δ-ex, $N^*(1440)$-ex, $S_{11}(1567)$-ex

N-pol, Δ-pol, $N^*(1440)$-pol, $S_{11}(1567)$-pol

KN : σ-ex, f_0-ex, a_0-ex

ρ-ex, ω-ex, ϕ-ex

Λ-ex, Σ-ex, $\Sigma^*(1385)$-ex

We determine the coupling constants and form factors so as to reproduce the experimental data of πN and KN scattering

Result for πN and KN scatt

πN scattering lengths

	calc	exp
S11	0.2470	0.2473±0.0043
S31	−0.1378	−0.1444±0.0057
P11	−0.2356	−0.2368±0.0058
P31	−0.1333	−0.1316±0.0058
P13	−0.0994	−0.0877±0.0058
P33	0.6254	0.6257±0.0058

fm**(2L+1)

KN scattering lengths

	calc	exp
S01	−0075	+0.00±0.02
S11	−0.353	−0.33±0.02
P01	+0.148	+0.08±0.02
P11	−0.098	−0.16±0.02
P03	−0.006	−0.13±0.02
P13	0.030	+0.07±0.02

fm**(2L+1)

$g_{\pi\pi\sigma}$ = -0.053

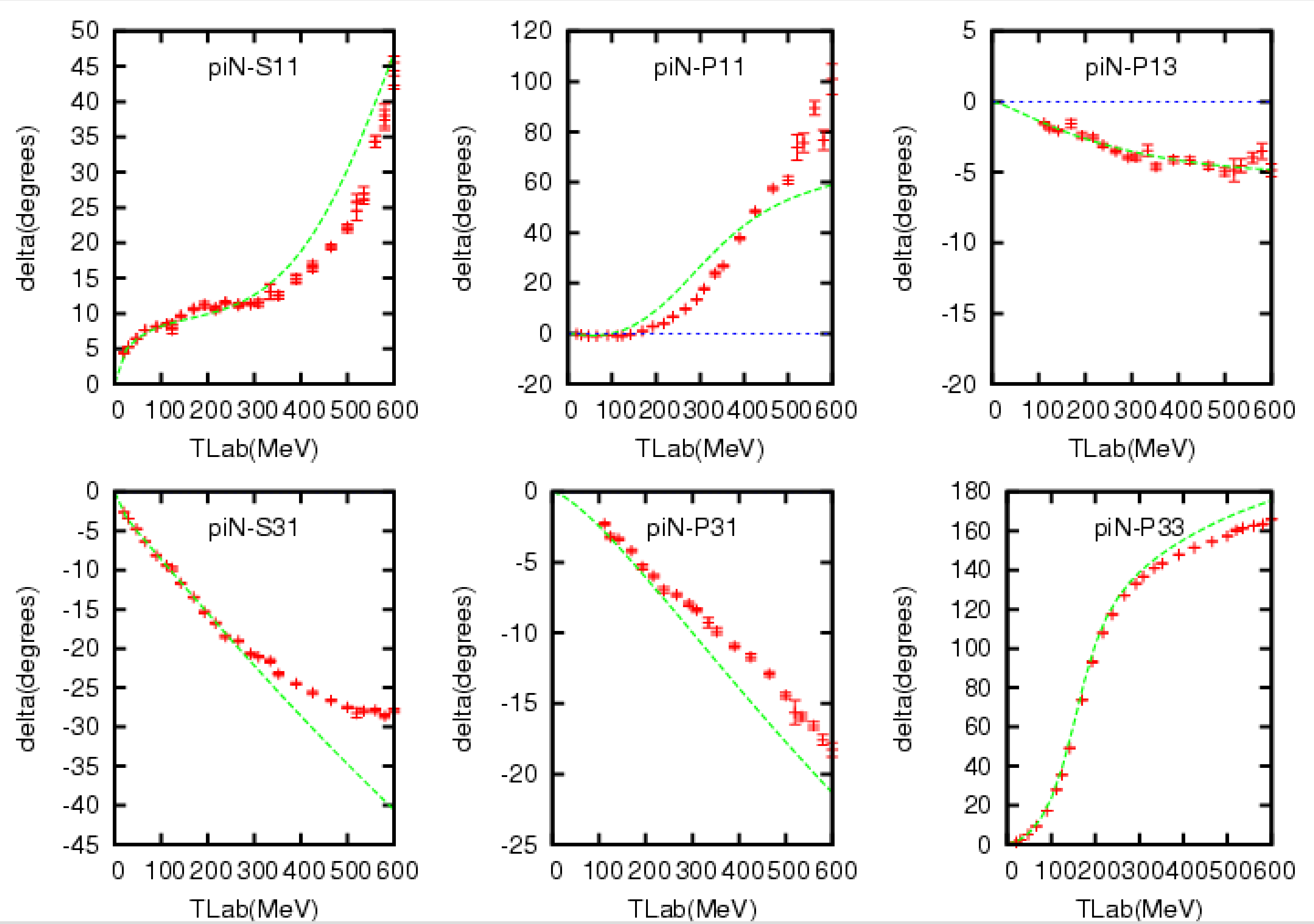
$g_{\pi\pi f_0}$ = 0.080

(Very weak σ-ex, f_0-ex)

We obtain also a reasonable fit for KN.

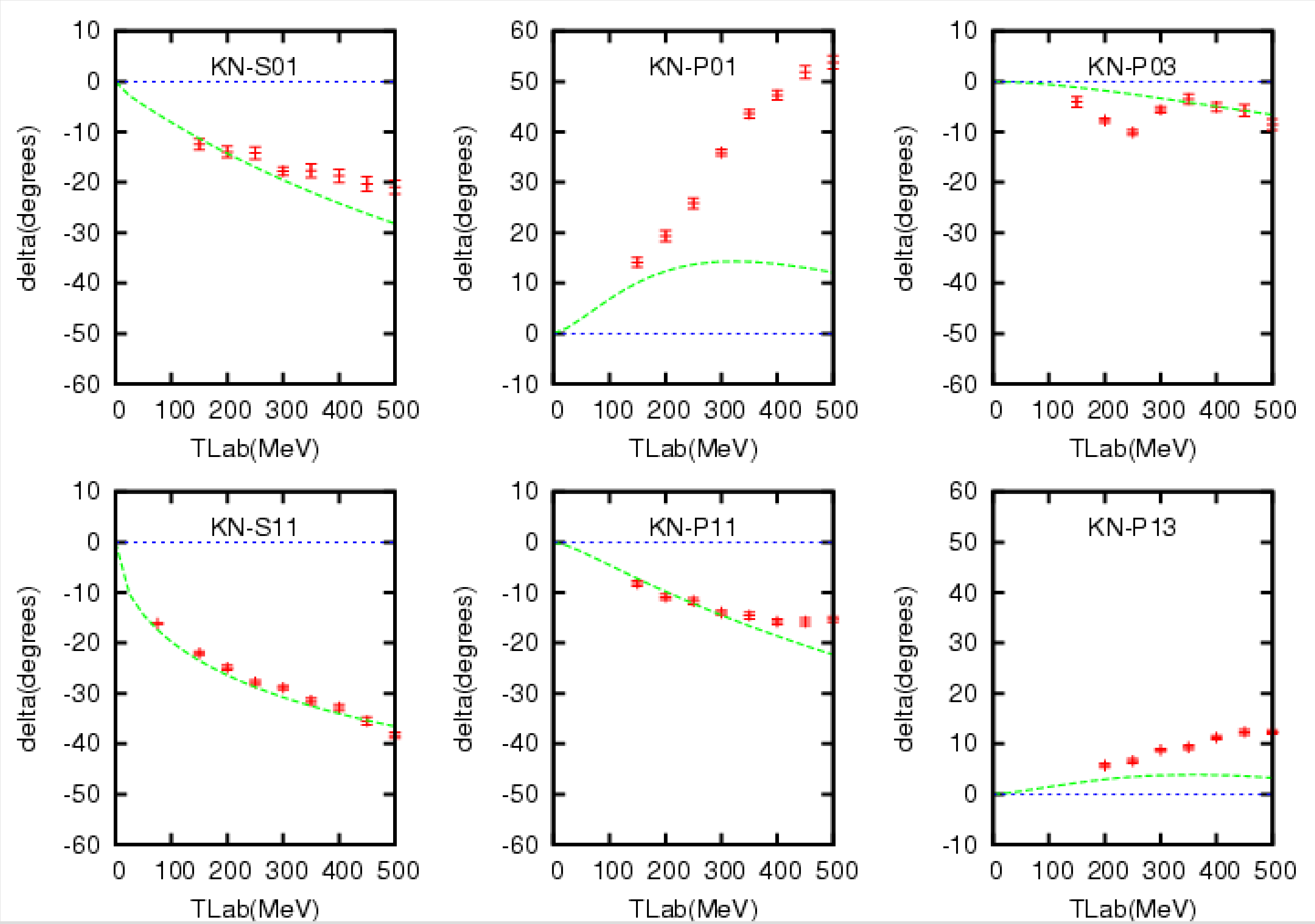
πN Phase Shifts

Exp(single-energy analysis) **Calculations**



KN Phase Shifts

Exp(single-energy analysis) **Calculations**



$\bar{K}N$ S-wave potential in our model

There is no adjustable parameter !!
(S-wave $\bar{K}N$ potential is determined by πN and
KN potentials.)

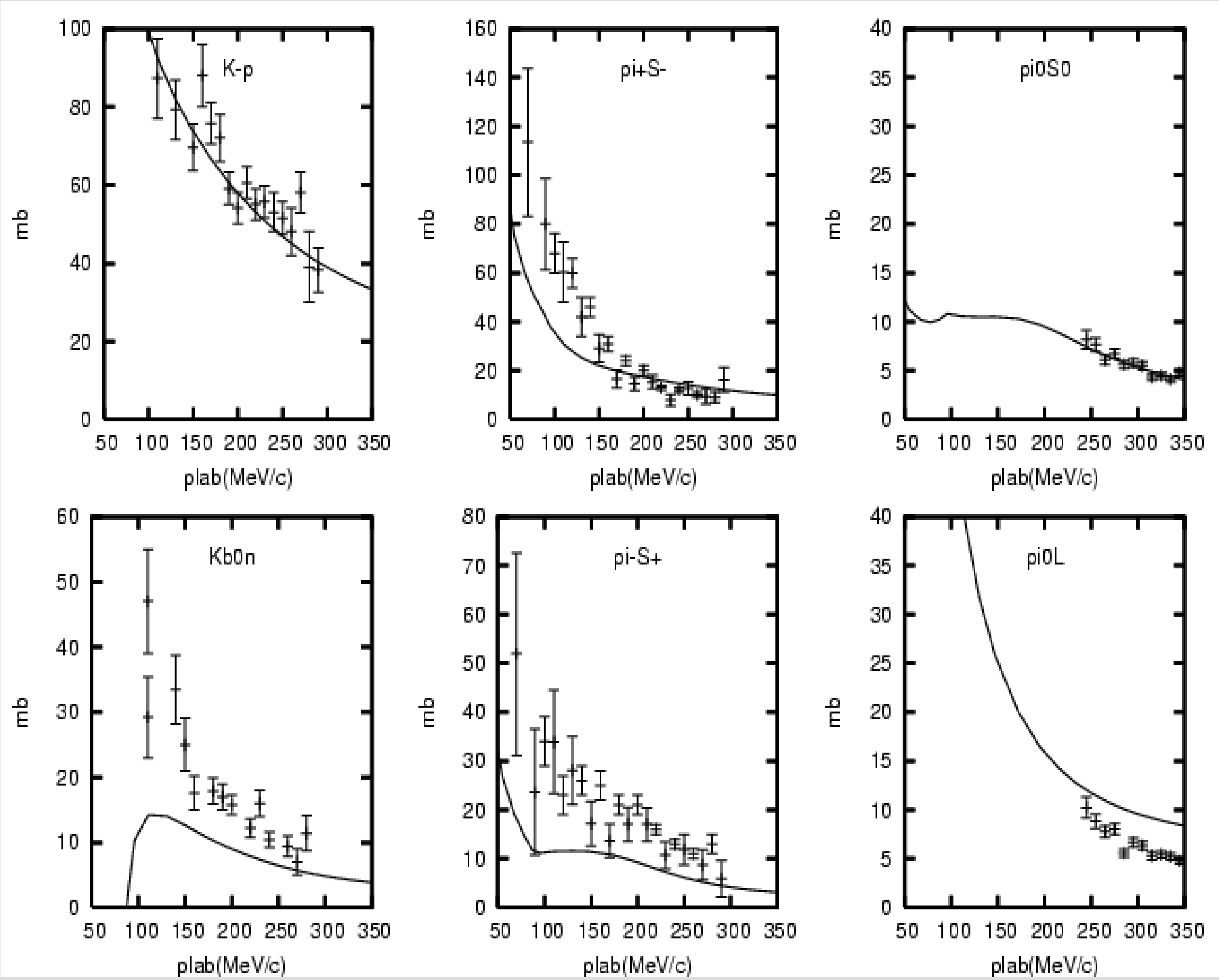
Isospin=0 channels

$\pi\Sigma - \bar{K}N - \eta\Lambda - K\Xi - \eta'\Lambda$

Isospin=1 channels

$\pi\Lambda - \pi\Sigma - \bar{K}N - \eta\Sigma - K\Xi - \eta'\Sigma$

$K^{-}p$ Reaction Cross sections



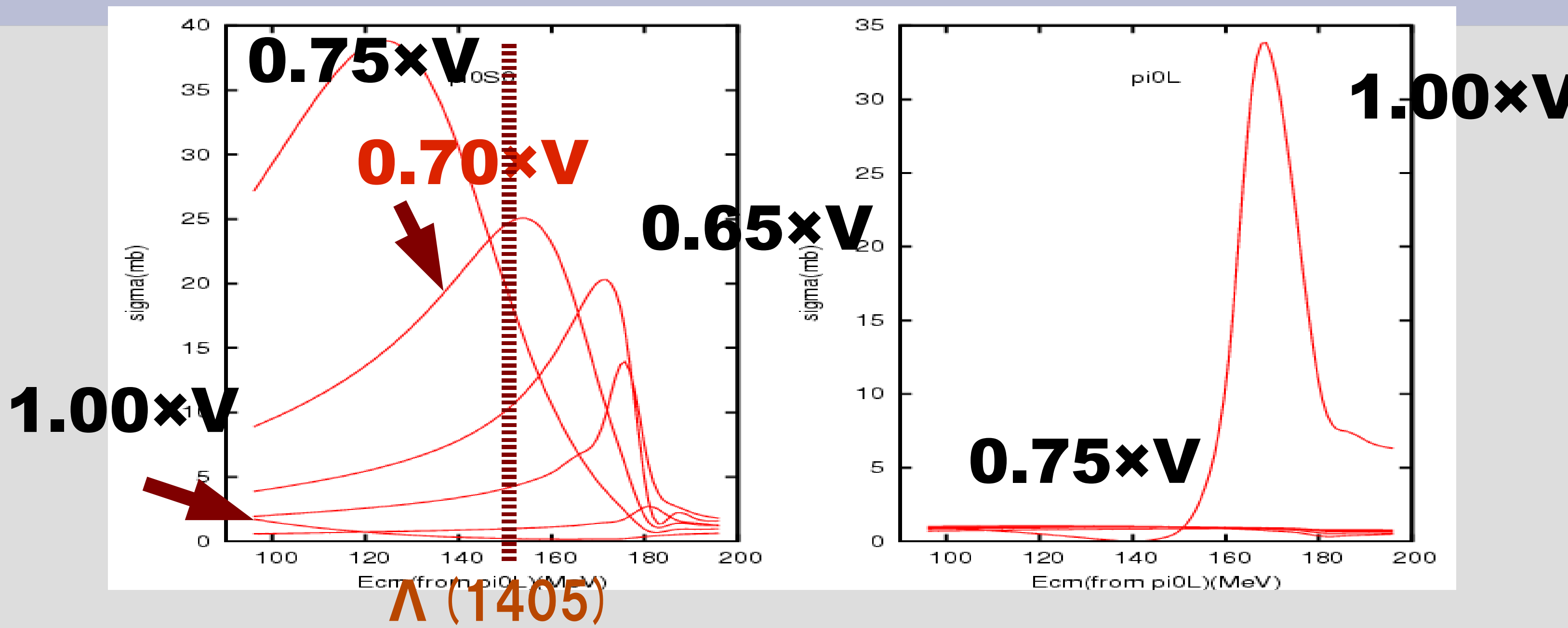
Fairly good agreement with experimental data

but

the Attraction in Isospin=0 is too strong.

$\pi^0\Sigma^0$ and $\pi\Lambda$ Elastic Cross Sections(S-wave)

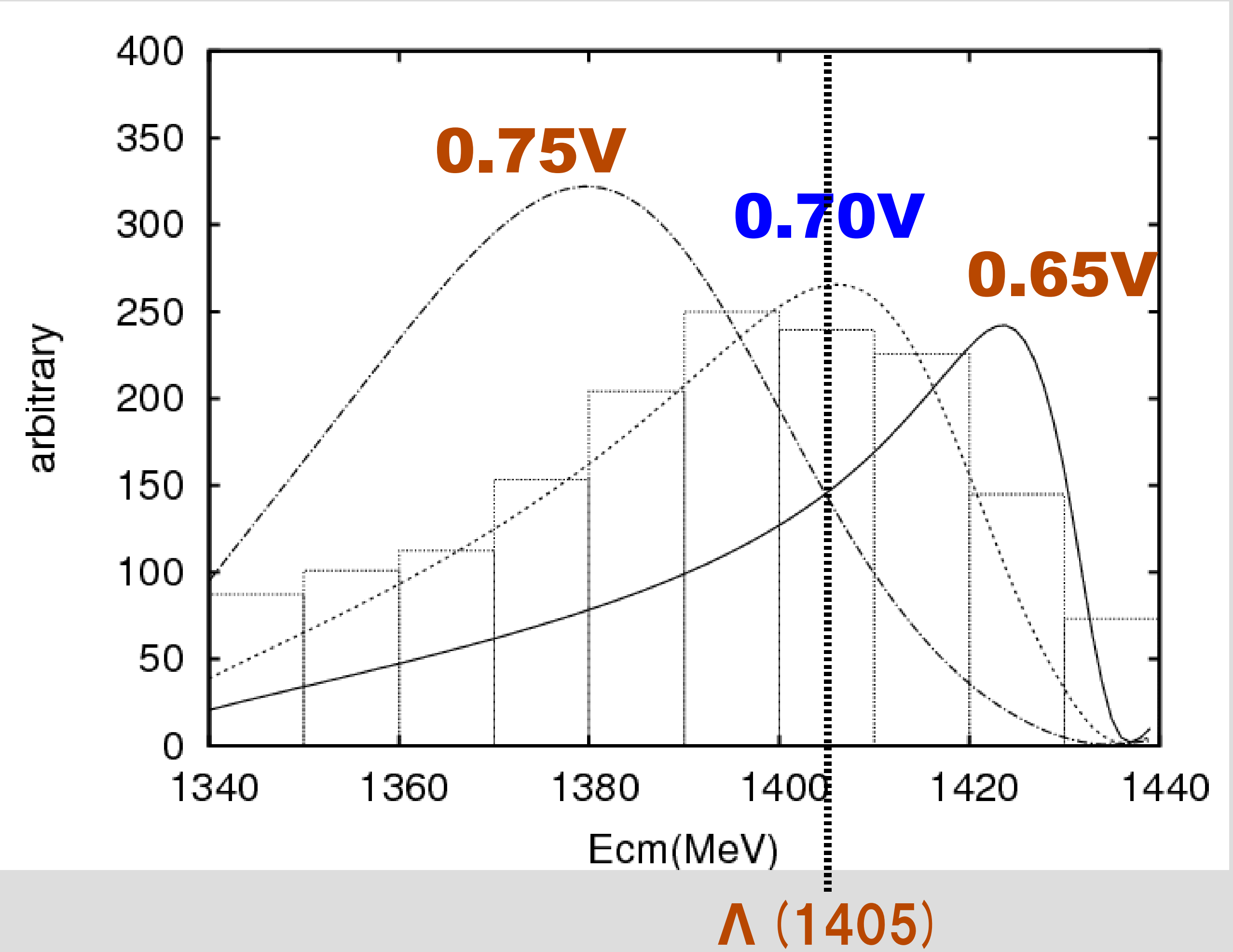
$\pi^0\Sigma^0$ $\pi^0\Lambda$(Isospin=1)



Isospin=0 Isospin=1

Strong Attraction! (a factor ～0.7 is needed)
(mainly from ω-ex)

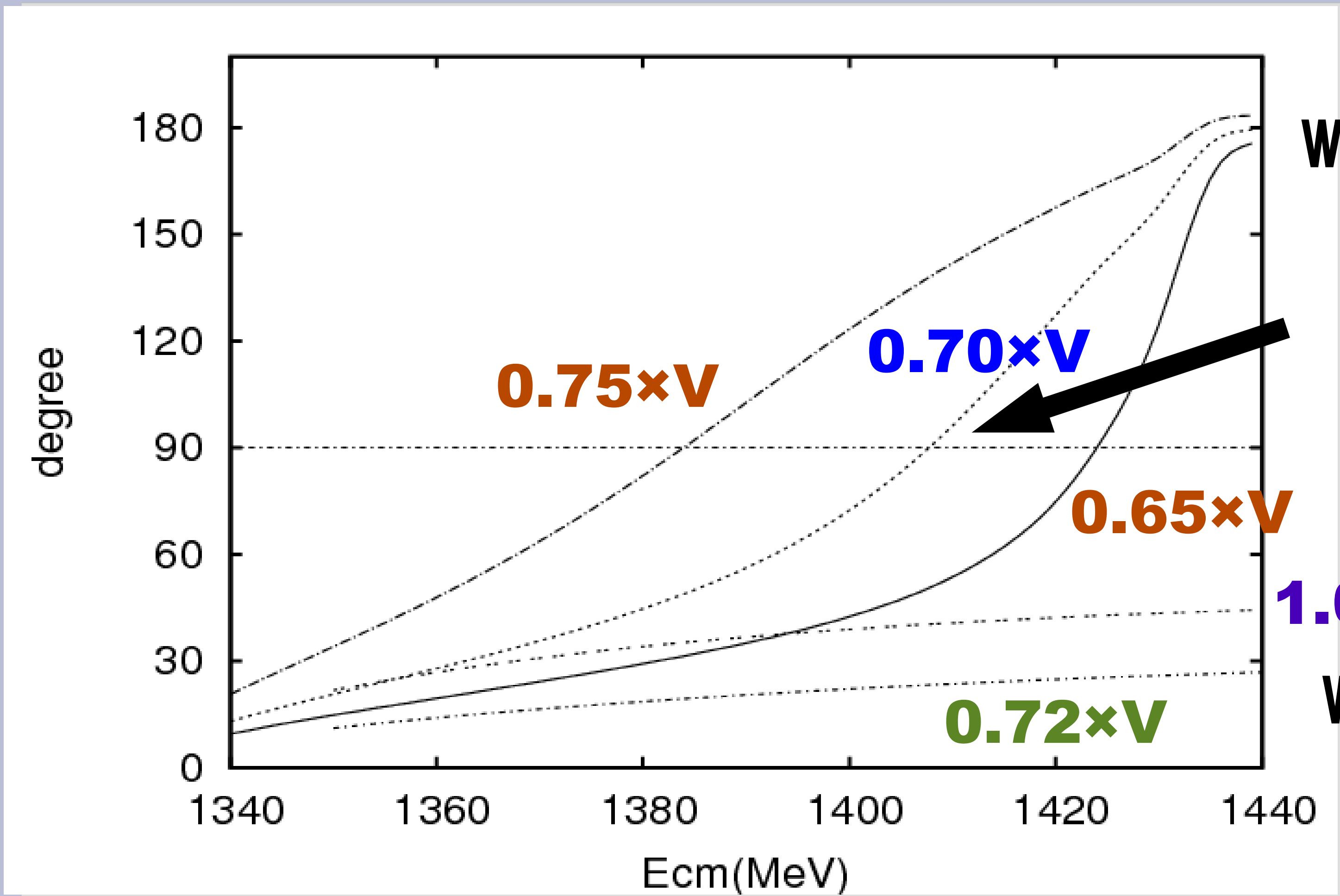
πΣ(I=0) Mass Spectrum



Our model reproduce the $\pi\Sigma$ mass spectrum by a factor around 0.70.

0.70V is best

π Σ S-Wave Phase Shifts (Isospin=0)



We have a single pole.

$K^{bar}N+\pi\Sigma$

We have no pole.

π Σ only

Branching Ratios at K^-p Threshold

$\gamma = \Gamma(K^-p \rightarrow \pi+\Sigma-)/\Gamma(K^-p \rightarrow \pi-\Sigma+)$

$R_c = \Gamma(K^-p \rightarrow \pi+\Sigma-, \pi-\Sigma+)/\Gamma(K^-p \rightarrow \text{all inelastic})$

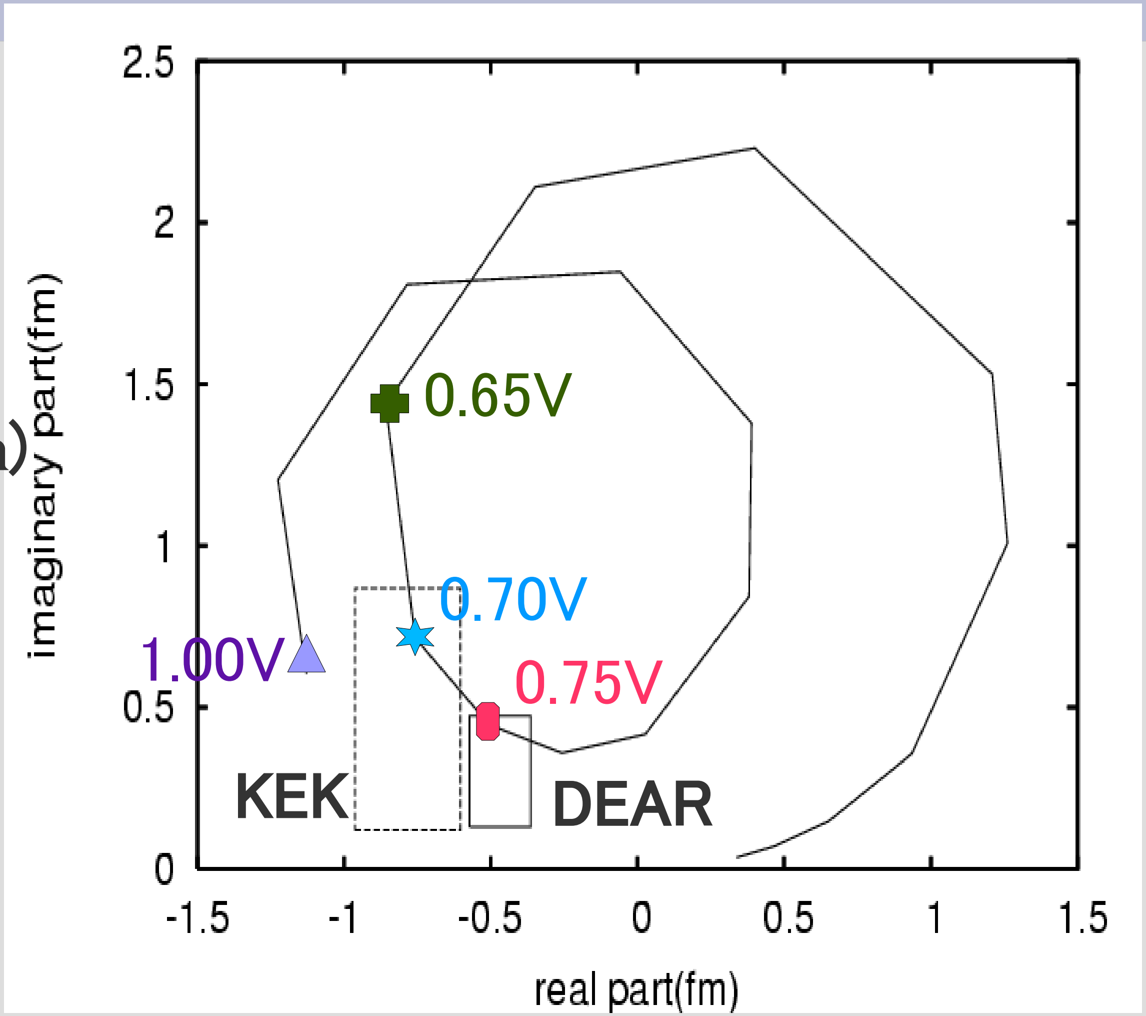
$R_n = \Gamma(K^-p \rightarrow \pi 0 \Lambda)/\Gamma(K^-p \rightarrow \text{neutral states})$

	Exp	1.00V	0.75V	0.70V	0.65V
γ	2.361±0.04	0.410	2.130	1.487	1.143
R_c	0.664±0.011	0.373	0.639	0.654	0.658
R_n	0.189±0.015	0.951	0.139	0.049	0.015

The ratios, γ and R_n are much sensitive to the interaction.

0.75V is best

K^-p scattering length



Im(a)

Re(a)

0.75V is supported by
DEAR data
Branching Ratios

0.70V is suppported by
KEK data.
Λ(1405) pole position

Experimental Data:
KEK : PRL78(1997)3067
DEAR : PRL94(2005)212302

Summary

○We propose a unified potential model of baryon-baryon and meson-baryon interactions.

○Our model predicts a strongly attractive $K^{bar}N$ potential. Quantitatively, this attraction is too strong to describe Λ(1405) as a quasibound state.

(0.70-0.75) V gives fairly reasonable results

○Using (0.70-0.75) V, we find

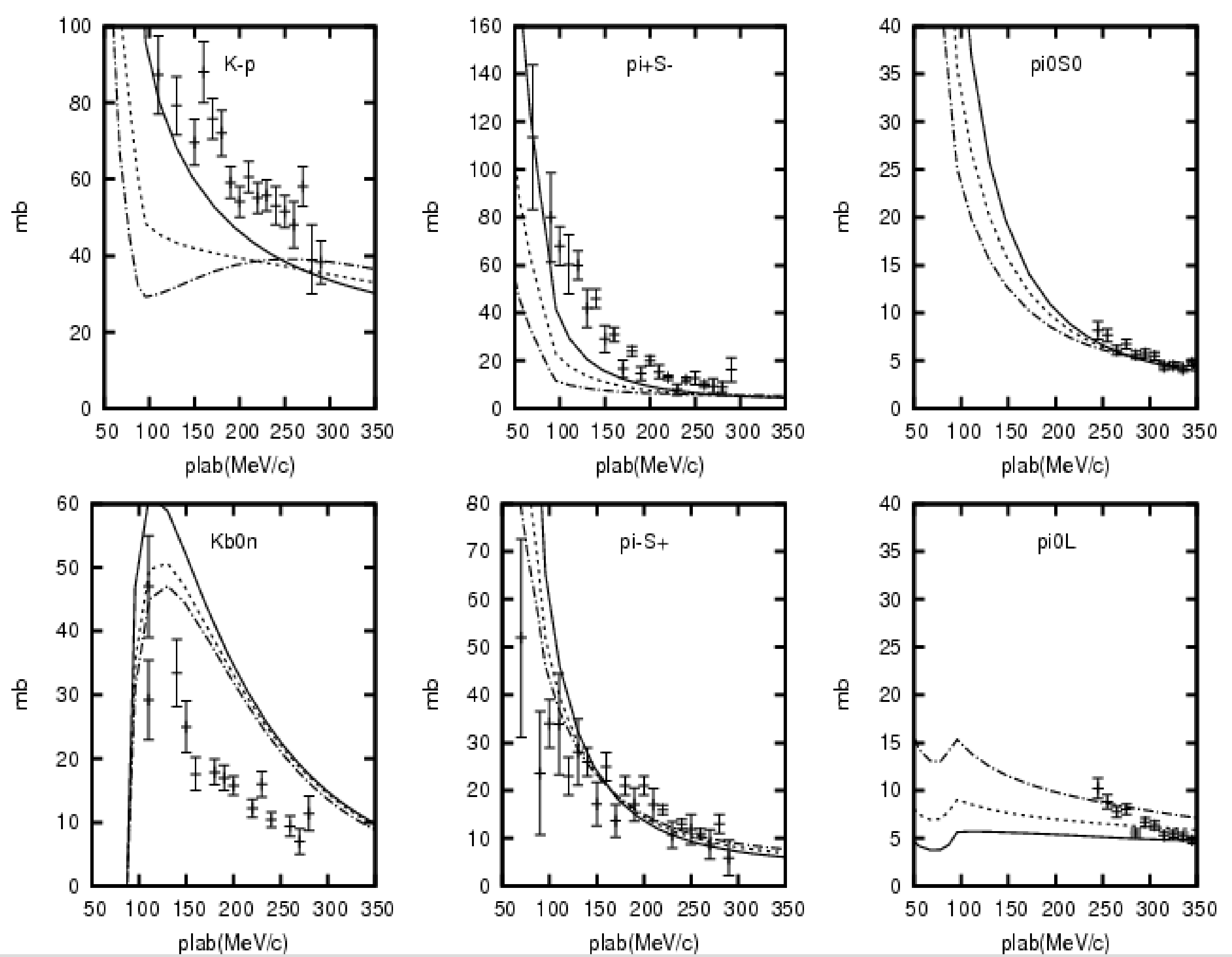
A single pole in $K^{bar}N$-$\pi\Sigma$ coupled-channel calculation

No pole in $\pi\Sigma$ single channel calculation

This pole corresponds to a quasibound state of $K^{bar}N$.

To remove the artificial factor=0.70-0.75,
Conbined analysis of BB and MB potentials are in progress.

K^-p Reaction Cross sections



Solid : 0.65V
Dotted : 0.70V
Dash-dotted : 0.75V