Meson-meson Interaction by one-meson-exchange mechanism

Ngo Thi Hong Xiem and Shoji Shinmura
Gifu University, Yanagido1-1, 501-1193,Gifu, Japan

GIFU UNIVERSITY

Introduction

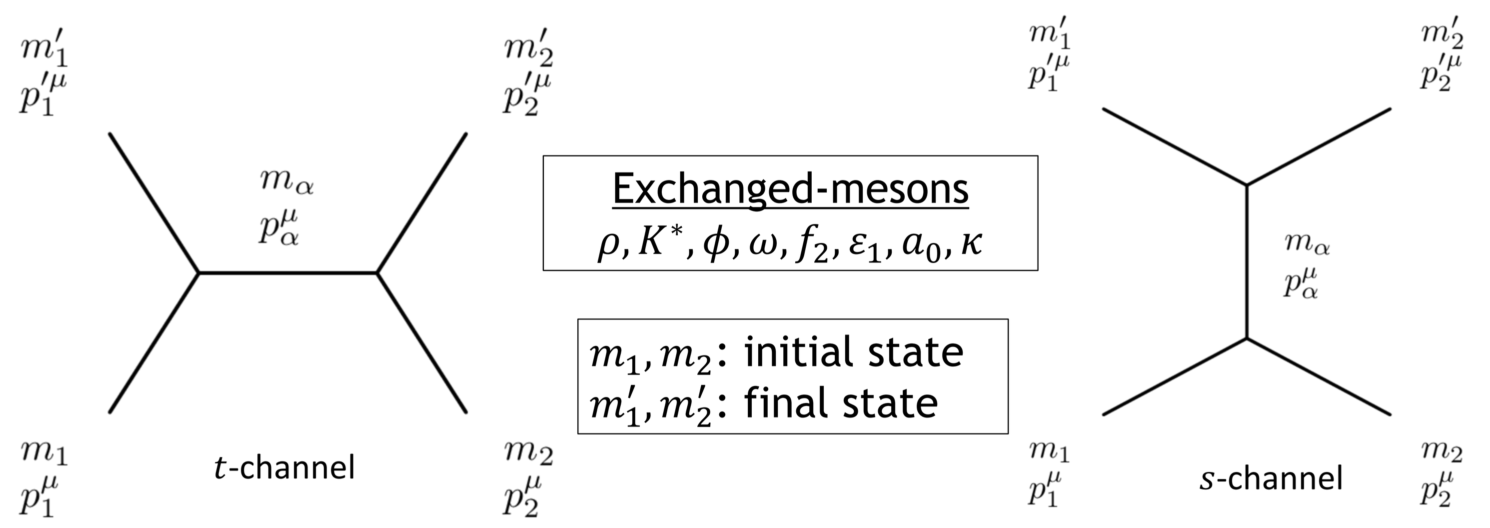
There are many theoretical models, i.e., lattice QCD, $SU(3)$ symmetric meson exchange[1] , $SU(3)$ or $SU(2)$ chiral perturbation model [2,3], which described meson-meson interaction. Using one-meson-exchange mechanism, we construct the following meson-meson interactions:

$$KK\ (S=2)$$
$$\pi K-\eta K\ (S=1)$$
$$\pi\pi-\bar{K}K-\pi\eta-\eta\eta\ (S=0)$$
$$\pi\bar{K}-\eta\bar{K}\ (S=-1)$$
$$\bar{K}\bar{K}\ (S=-2).$$

By the S-matrix calculations on the complex-E plane, we find the resonances corresponding to $a_0(980), f_0(980), f_2(1270), \kappa(1430), \kappa(700), \rho(770), K^*(982)$, $\phi(1020)$ and $\sigma_1(600)$.

Hadron-Hadron Interactions

Feynman diagrams contribute to the meson-meson interaction



Flavor $SU(3)$ –symmetric coupling constants

$$\mathcal{L}_{pps} = \frac{f_{pps}}{m_\pi} \boldsymbol{Tr}[\partial^\mu P \partial_\mu PS]$$
$$\mathcal{L}_{ppv} = g_{ppv} \boldsymbol{Tr}[((\partial^\mu P)P - P(\partial^\mu P))V]$$
$$\mathcal{L}_{ppt} = g_{ppt} \frac{2}{m_\pi} \boldsymbol{Tr}[(\partial_\mu P \partial^\nu P) T^{\mu\nu}]$$

- f_{pps}, g_{ppv}, g_{ppt}: coupling constants
- P : 3×3 matrix representation of the pseudo-scalar octet.
- S : 3×3 matrix representation of the scalar octet.
- V : 3×3 matrix representation of the vector octet.

Form factors

Monopole Type

t-channel

$$F^{(t)}(\boldsymbol{q}^2_\alpha) = \frac{\Lambda^2 - m^2_\alpha}{\Lambda^2 + \boldsymbol{q}^2_\alpha}$$

s-channel

$$F^{(s)}(\omega^2_p) = \frac{\Lambda^2 + m^2_\alpha}{\Lambda^2 + \omega^2_p}$$

Gaussian Type

t-channel

$$F^{(t)}(\boldsymbol{q}^2_\alpha) = \exp\left(-\frac{\boldsymbol{q}^2_\alpha}{\Lambda^2}\right)$$

s-channel

$$F^{(s)}(\omega^2_p) = \exp\left(-\frac{\omega^2_p}{\Lambda^2}\right)$$

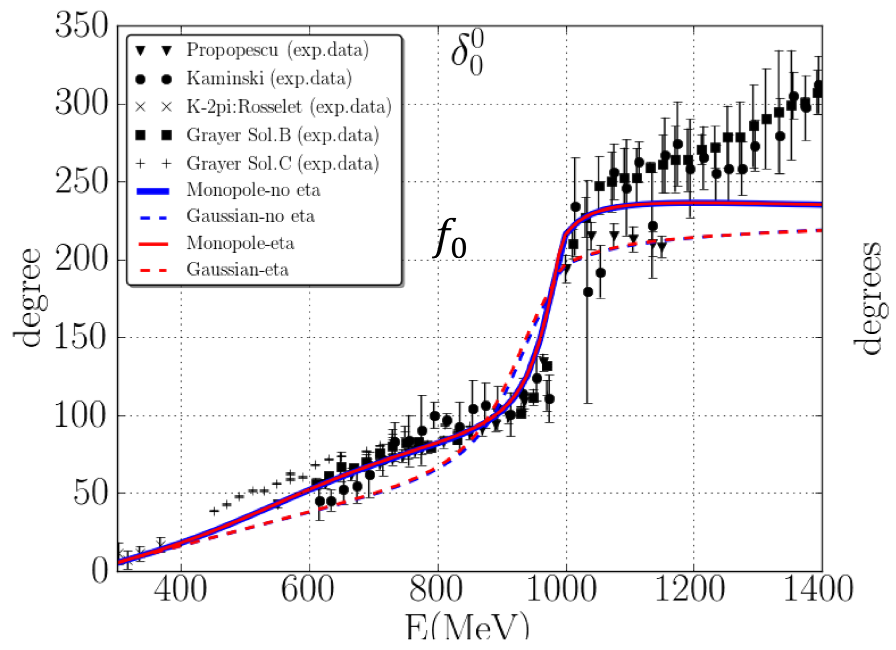
Λ (MeV) cut-off parameter
m_α mass of exchanged meson
ω_p total energy
q_α momentum

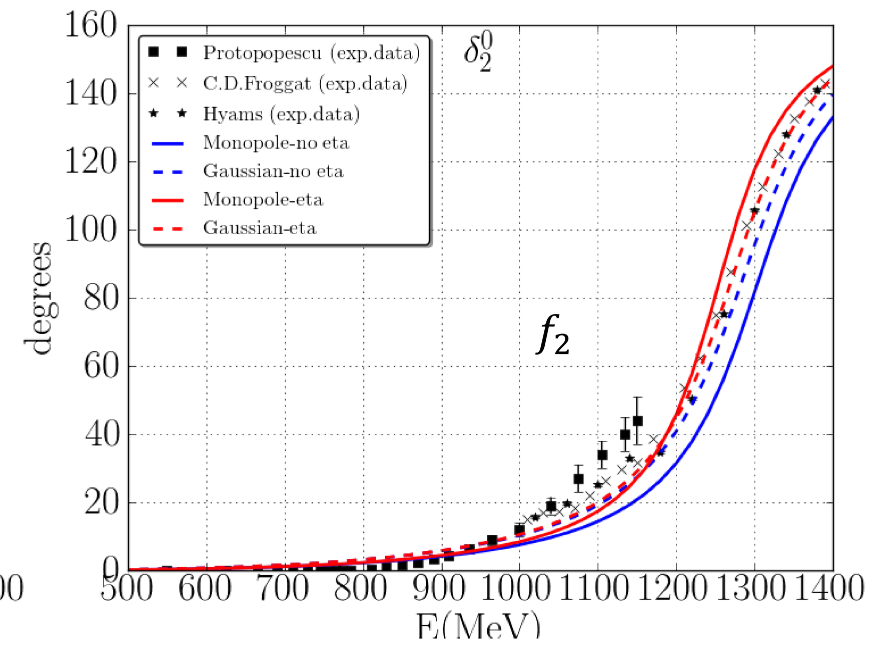
Scattering lengths

a^I_J	Exp. Data	Monopole-η	Gaussian-η
a^0_0	0.223 ± 0.009	0.199904	0.207372
a^0_2	0.001833 ± 0.000036	0.002732	0.004021
a^1_1	0.0381 ± 0.0009	0.077404	0.066641
a^2_0	-0.0444 ± 0.0045	−0.01778	−0.021126
a^2_2	0.000246 ± 0.000025	−0.00073	−0.000825
a^1_0		0.034647	0.01479
a^0_1		0.212526	0.155126
$a^{1/2}_0$	0.224 ± 0.022	0.378536	0.407038
$a^{1/2}_1$	0.019 ± 0.001	0.038733	0.032482
$a^{3/2}_0$	-0.0448 ± 0.0077	−0.0571	0.059452
$a^{3/2}_1$	-0.00065 ± 0.00044	−0.00138	0.000767

Results

We obtained the phase shifts δ^I_J, where I and J are the isospin and the total angular momentum.

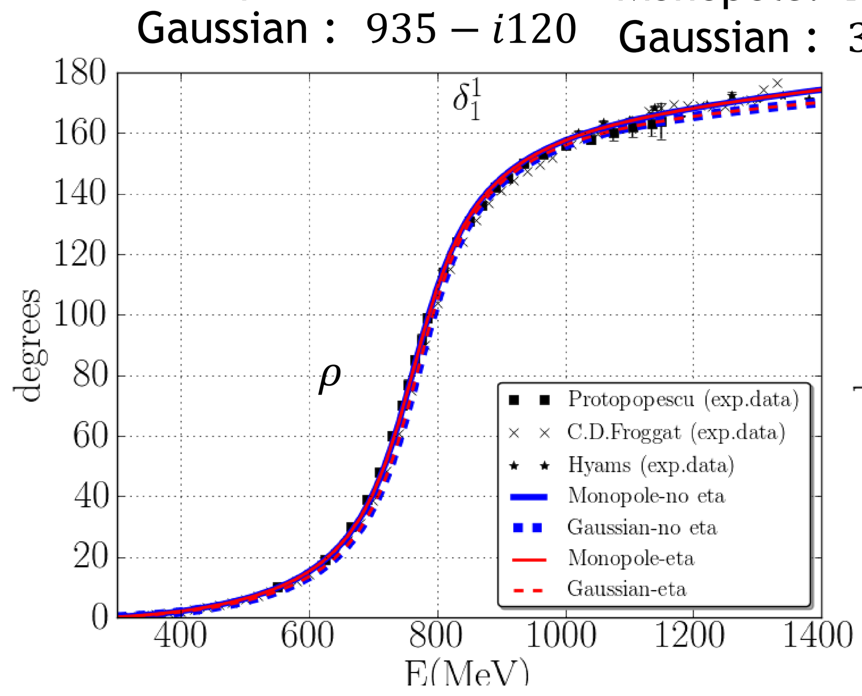


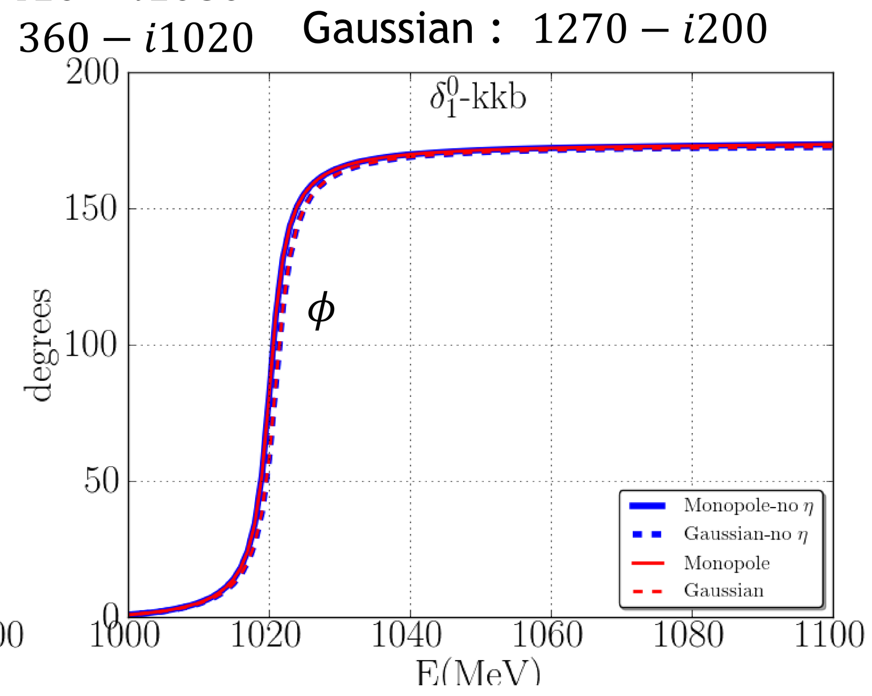


$f_0(980)$
Monopole: $975 - i72$
Gaussian : $935 - i120$

$\sigma_1(600)$
Monopole: $410 - i1080$
Gaussian : $360 - i1020$

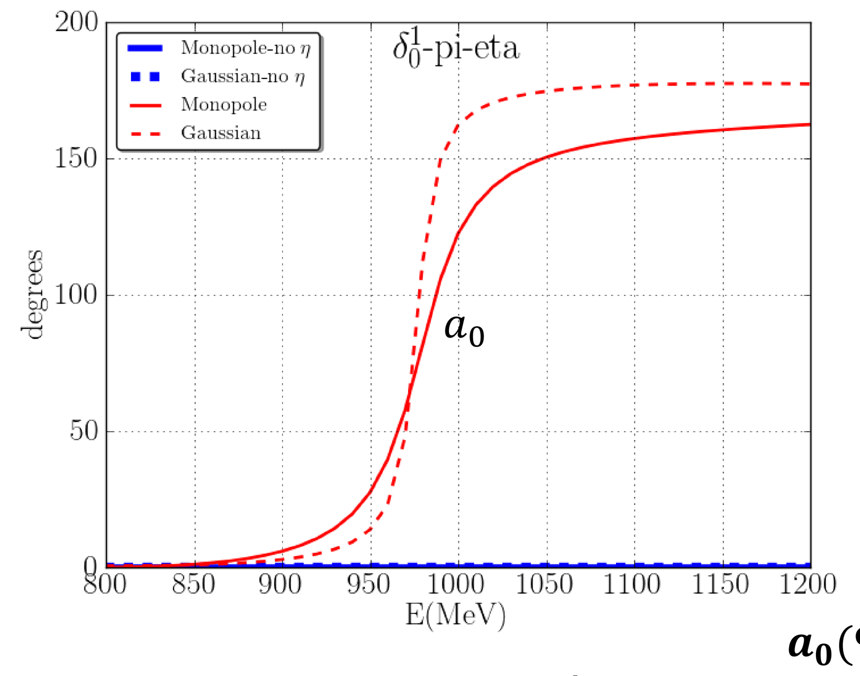
$f_2(1270)$
Monopole: $1244 - i156$
Gaussian : $1270 - i200$

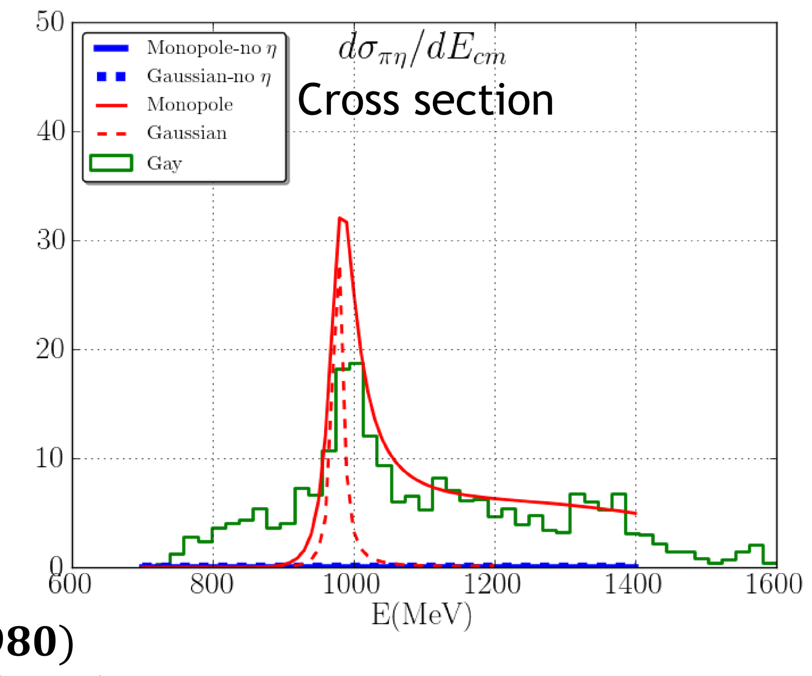




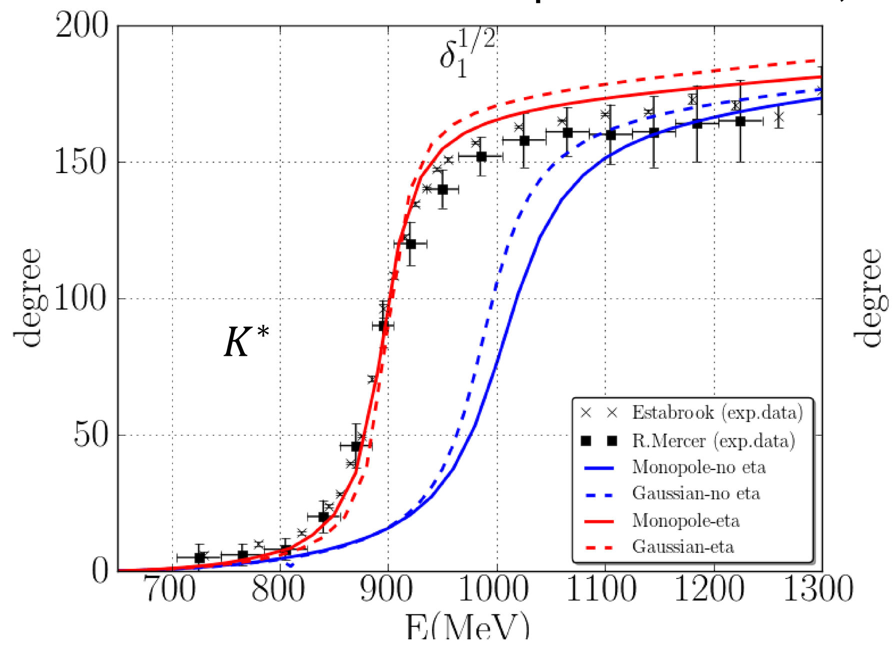
$\rho(770)$
Monopole: $800 - i120$
Gaussian : $800 - i120$

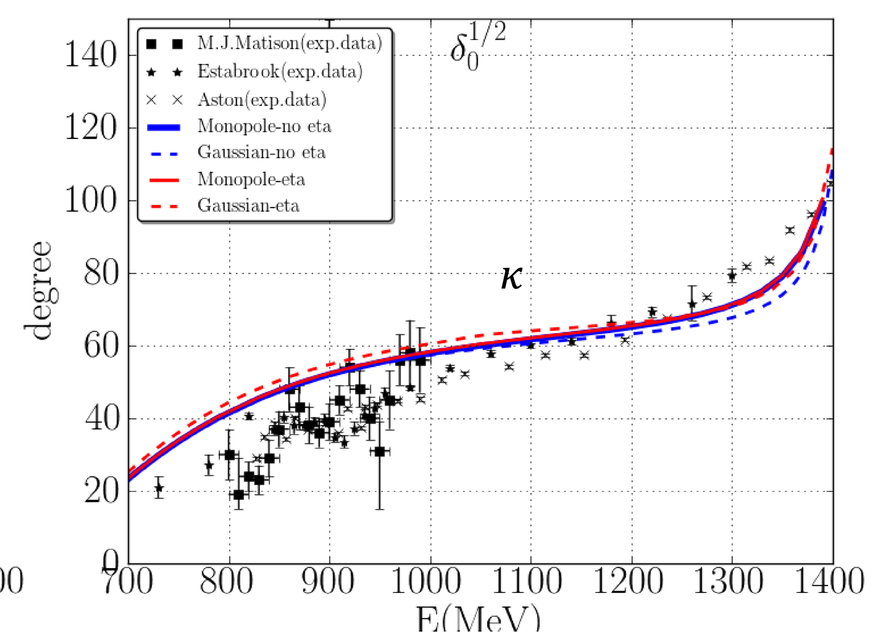
$\phi(1020)$
Monopole: $1020 - i4$
Gaussian : $1021 - i4$





$a_0(980)$
Monopole: $857 - i56$; Gaussian: $860 - i40$





$K^*(892)$
Monopole: $905 - i40$
Gaussian : $910 - i36$

$\kappa(1430)$
Monopole: $1420 - i46$
Gaussian : $1410 - i34$

$\kappa(700)$
Monopole: $650 - i400$
Gaussian : $649 - i380$

Conclusion

Based on the SU(3)-symmetric one-meson-exchange, we described the phase shifts of $\pi\pi - K\bar{K} - \pi\eta - \eta\eta$ and $\pi K - \eta K$ interactions in low-energy region ($\sqrt{s} < 1.5$GeV). Beside the well-reproduced poles of $f_0(980), \rho(770)$, $f_2(1270), \kappa(1430), K^*(892)$, we also found the existence of the $a_0(980), \phi(1020), \sigma_1(600)$ and $\kappa(700)$.

References

1. D. Lohse, J.W. Durso, K. Holinde, and J. Speth, Nucl. Phys. A516, 513 (1990).
2. J.A. Oller and E. Oset, Nucl. Phys. A620, 438 (1997).
3. J.A. Oller, E. Oset, and J.R. Pelaez, Phys. Rev. D59, 074001 (1999).
4. S. R. Beane, et al., Phys. Rev. D77, 094507 (2008).
5. Y. Kanada-En'yo and D. Jido, Phys. Rev. C78, 025212 (2008).
6. N. T. H. Xiem and S. Shinmura, Prog. Theor. Exp. Phys. (2014).