σ AND κ MESONS AS BROAD DYNAMICAL RESONANCES IN ONE-MESON-EXCHANGE MODEL

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2. One meson exchange potential
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Introduction

- Many model of meson-meson interaction
  - Quark Model
  - Chiral perturbation
    - J.A.Oller, E.Oset, Nucl.Phys A620, 438-456(1997).
    - J.A.Oller, E.Oset, Phys. Rev. D 59, 074001 (1999).
    - A.G.Nicola and J.R.Pelaez arXiv:help-ph/0109056v2 (2001).
  - LQCD
    - Silas R. Beane, Thomas C. Luu et al, Phys. Rev D 77, 094507 (2008).
  - Meson exchange model
    - D. Lohse et al, Nuc. Phys. A516, 513-548 (1990).
- In meson-meson interaction $\pi\pi$, πK scatterings have been investigated both in experiments and theories.
- Construct a unified hadron-hadron potential model which appropriate for all BB, MB and MM interactions.
- Meson-exchanged models keeps its validity as a suitable effective description of the h-h interactions in the low-energies region.

Introduction

- By $SU(3)$-symmetric one-meson exchange mechanisms, we construct:
  - $K^{bar}K^{bar}$ (S = -2)
  - $\pi K^{bar} - \eta K^{bar}$ $(S = -1)$
  - $\pi\pi - KK^{bar} - \eta\pi - \eta\eta$ $(S = 0)$
  - $\pi K - \eta K(S = 1)$
  - KK $(S = 2)$

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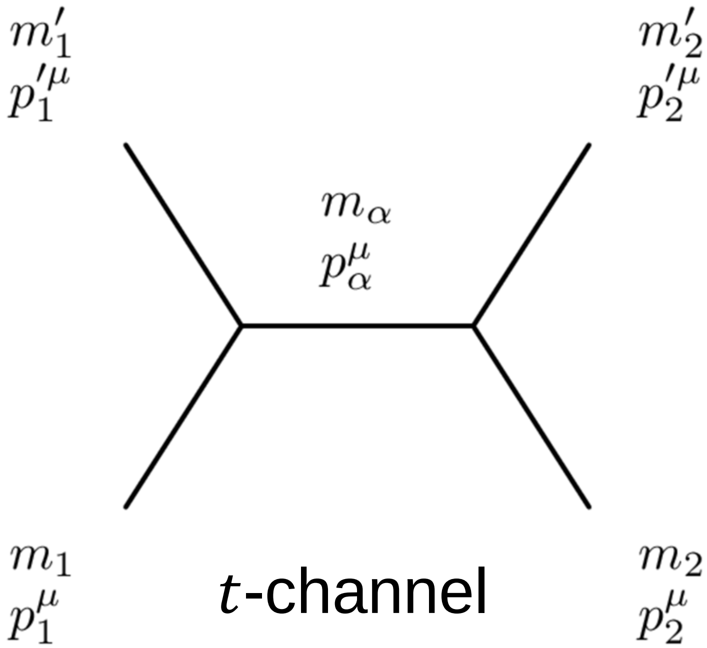
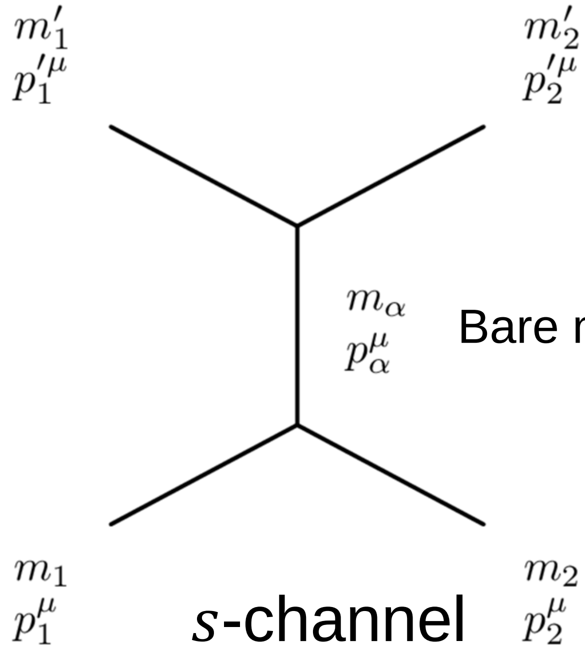
Meson exchange potential

- Feynman Diagram

Exchange-meson

$\rho, K^*, \phi, \omega, f_2, \varepsilon_1, a_0, \kappa$





Bare mass.

Meson exchange potential

- Interaction Lagrangians
- Interaction Hamiltonian $W = -\int L d^3x$
- Transition operator $T(z)$ are represented by a series expansion defined by all diagrams containing an incoming and outgoing two-meson state.
- One meson potential can determined

Coupling constants

- SU(3) Symmetric Lagrangians

$$\mathcal{L}_{pps} = \frac{f_{pps}}{m_\pi} \boldsymbol{Tr}\left[\partial^\mu P \partial_\mu P S\right]$$

$$\mathcal{L}_{ppv} = g_{ppv} \boldsymbol{Tr}[((\partial^\mu P)P - P(\partial^\mu P))V]$$

$$\mathcal{L}_{ppt} = g_{ppt} \frac{2}{m_\pi} \boldsymbol{Tr}\left[(\partial_\mu P \partial^\nu P)T^{\mu\nu}\right]$$

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

- $$P_8 = \begin{pmatrix} \frac{\pi_0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & -\frac{\pi_0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & -\sqrt{\frac{2}{3}}\eta_8 \end{pmatrix};$$

$$P_1 = \eta_1$$

- $$V_8 = \begin{pmatrix} \frac{\rho^0}{\sqrt{2}} + \frac{\phi}{\sqrt{6}} & \rho^+ & K^{*+} \\ \rho^- & -\frac{\rho^0}{\sqrt{2}} + \frac{\phi}{\sqrt{6}} & K^{*0} \\ K^{*-} & \bar{K}^{*0} & -\sqrt{\frac{2}{3}}\phi \end{pmatrix};$$

$$V_1 = \omega$$

- $$S_8 = \begin{pmatrix} \frac{a_0}{\sqrt{2}} + \frac{f_0}{\sqrt{6}} & a^+ & \kappa^+ \\ a^- & -\frac{a_0}{\sqrt{2}} + \frac{\phi}{\sqrt{6}} & \kappa^0 \\ \kappa^- & \bar{\kappa}^0 & -\sqrt{\frac{2}{3}}\phi \end{pmatrix};$$

$$S_1 = \sigma$$

Form Factors

- Monopole Type
  - t-channel
    - $F^{(t)}(q_\alpha^2) = \frac{\Lambda^2 - m_\alpha^2}{(\Lambda^2 + q_\alpha^2)}$
  - s-channel
    - $F^{(s)}(\omega_p^2) = \frac{\Lambda^2 + m_\alpha^2}{(\Lambda^2 + \omega_p^2)}$
  - Forth-order (s-channel)
    - $F_4(\omega_p^2) = \frac{\Lambda^4 + m_\alpha^4}{(\Lambda^4 + \omega_p^4)}$

Λ : cut-off parameters

q_α: momentum

m_α: mass of exchanged mesons

ω_α : total energy

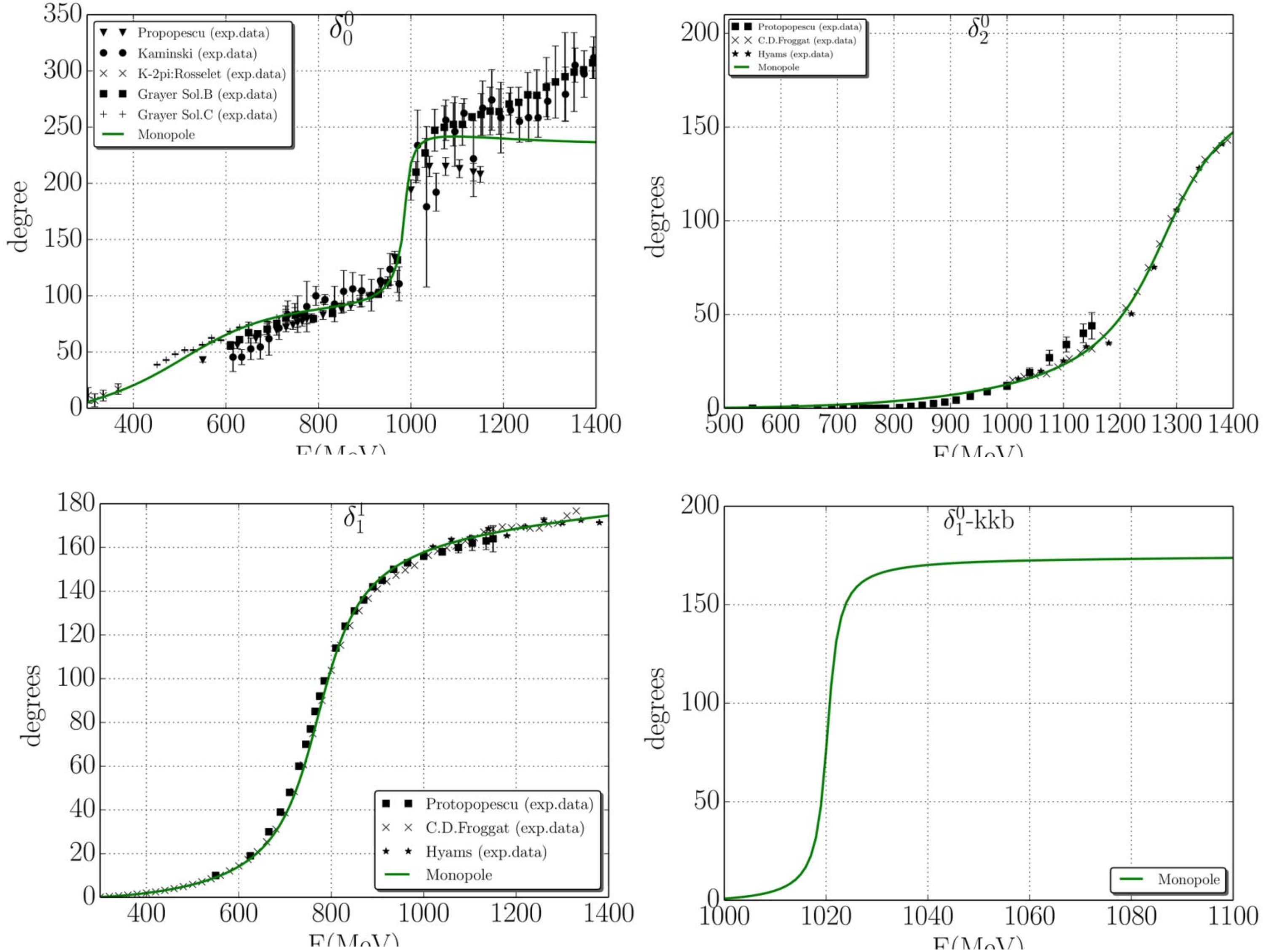
Parameters

m_0	Mono.
ρ	1126.66877
ε_1	2112.07666
K^*	1403.13526
κ	1522.01264
f_2	1367.63563

	Mono.
$\Lambda_{\eta K K^*}$	864.0841
$g_{KK^{bar}a_0}$	0.0408802
$\Lambda_{KK^{bar}a_0}$	1233.61523
$m_0(a_0)$	1235.73076
$\Lambda_{KK^{bar}\phi}$	2137.02377
$m_0(\phi)$	1150.23241

	Monopole
$g_{\pi\pi\rho}$	0.50101
$g_{\pi\pi f_2}$	0.02843626
$g_{\pi\pi\varepsilon_1}$	0.01620557
$g_{\pi\pi\kappa}$	0.191683×10^{-3}
$\Lambda_{\pi\pi\rho}$	2896.41242
$\Lambda_{\pi K K^*}$	2301.47525
$\Lambda_{K\bar{K}\rho}$	3923.01907
$\Lambda_{K\bar{K}\omega,\phi}$	4520.8249
$\Lambda_{\pi\pi\rho-sch}$	2757.75065
$\Lambda_{\pi\pi f_2-sch}$	1481.43534
$\Lambda_{\pi\pi\varepsilon_1-sch}$	1159.73371
$\Lambda_{\pi K K^*-sch}$	4061.81573
$\Lambda_{\pi K\kappa-sch}$	3622.67379

Phase shift results

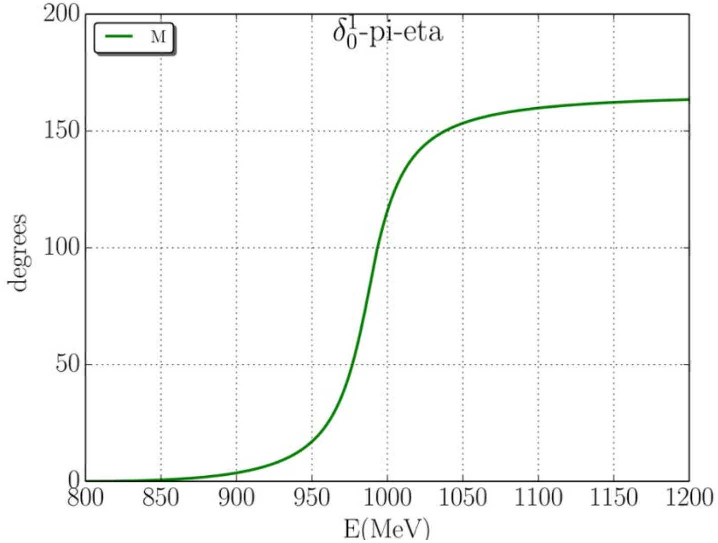


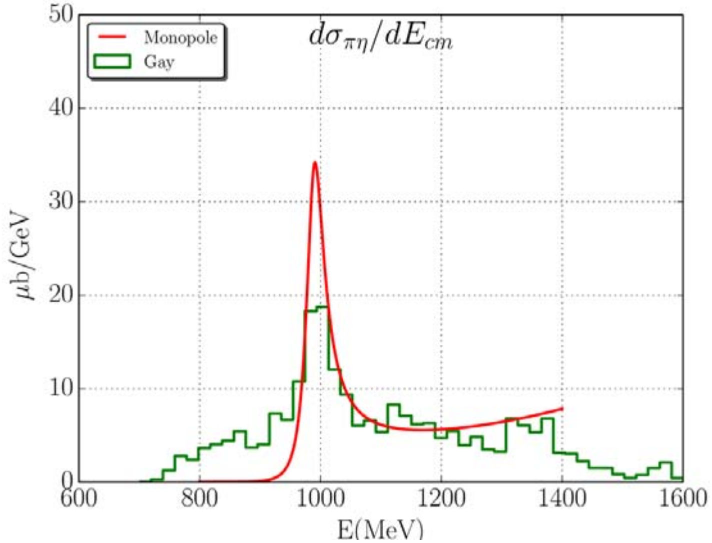
δ_J^I

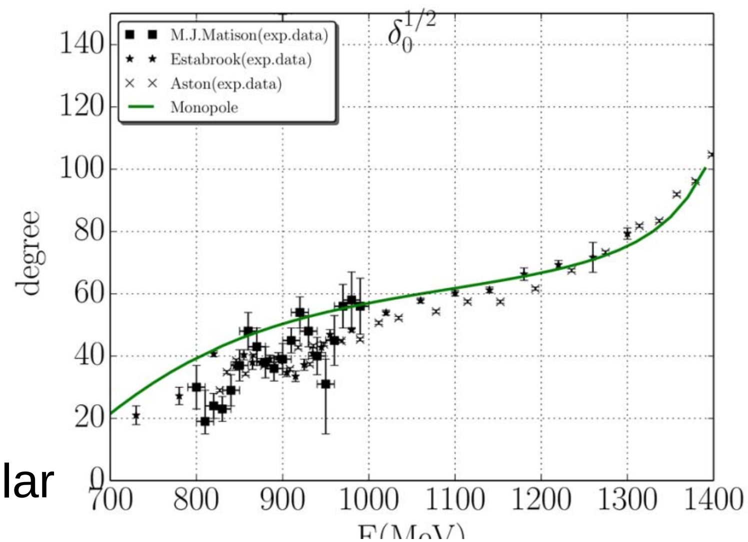
I: isospin

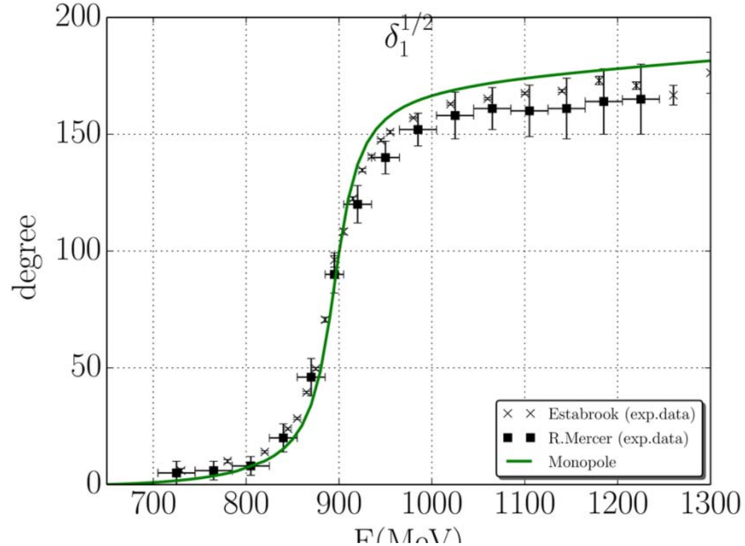
J: total angular momentum

Phase shift results









δ_J^I

I: isospin

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Resonances

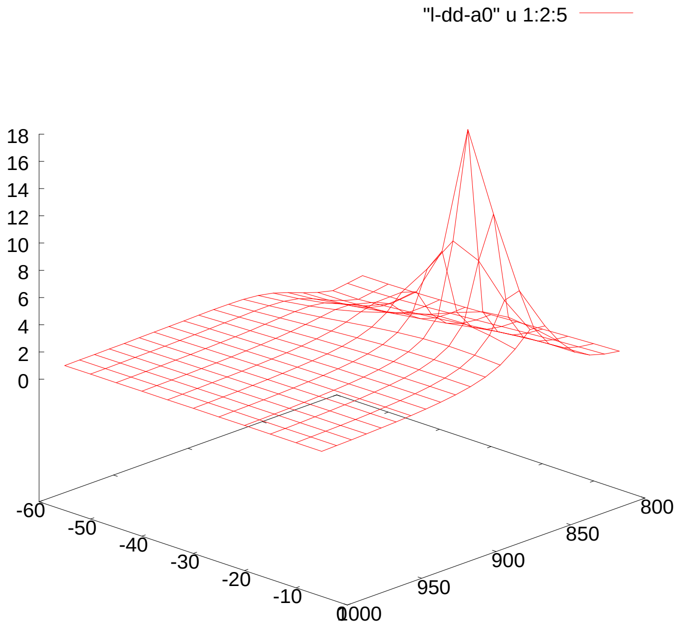
Poles with s-channel meson exchange

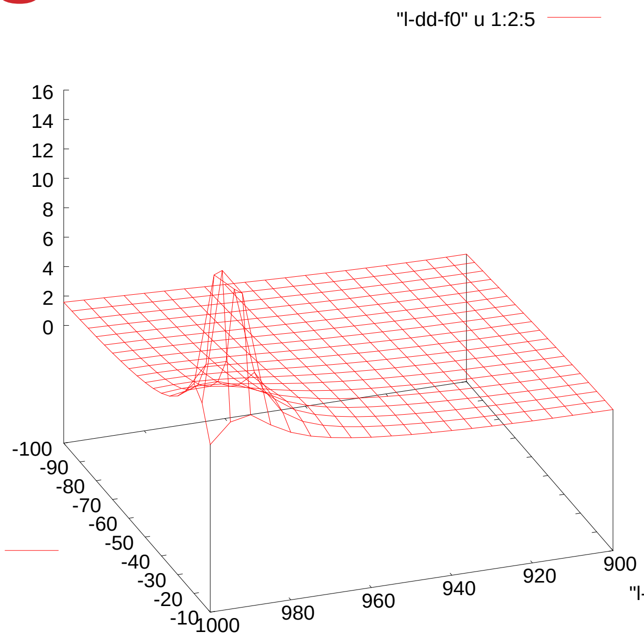
- $V = V_t + V_s$
  - V_s contains s-channel diagrams
  - V_t contains t-channel diagrams
  - $V_s(p', p) = \sum_i \gamma_i(p')\Delta_{\mathrm{i}}(\mathrm{P})\gamma_i(p)$ with bare mass and bare coupling constant
- $T = T_t + T_s$
  - $T_s = \gamma^*(p')\Delta^*(\mathrm{P})\gamma^*(\mathrm{p})$
  - $\Delta^*(P) = \frac{\Delta(P)}{1-\Delta(P)\Sigma(\mathrm{p})}$: dressed propagator
  - $\Sigma(p)$: self-energy
  - $\gamma^*(p)$: dressed vertex

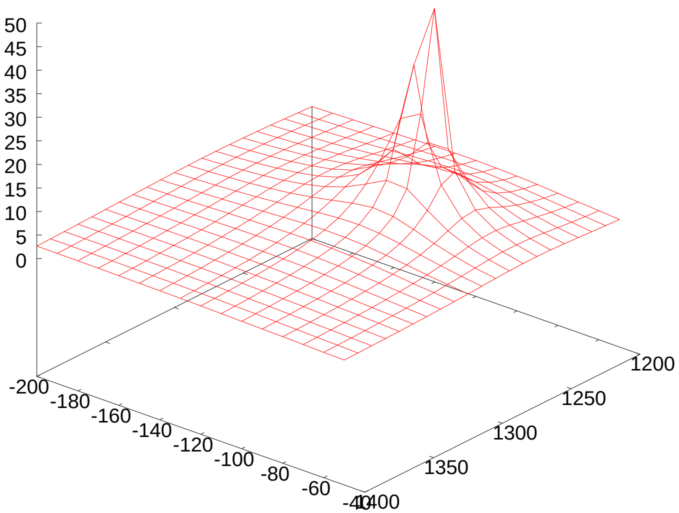
Pure Dynamical Poles (without s-channel exchange)

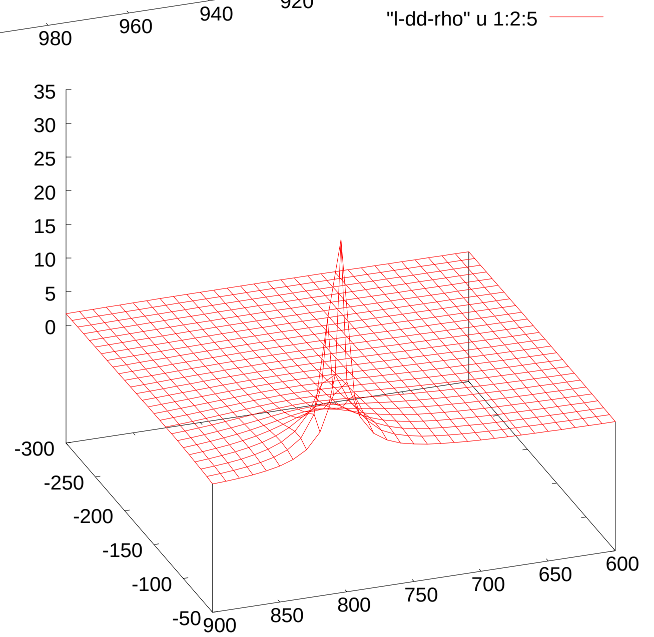
*This resonance renormalization follow: H.Polinder an Th. A. Rijken Phys. Rev. C 72, 065211 (2005)

Resonances results

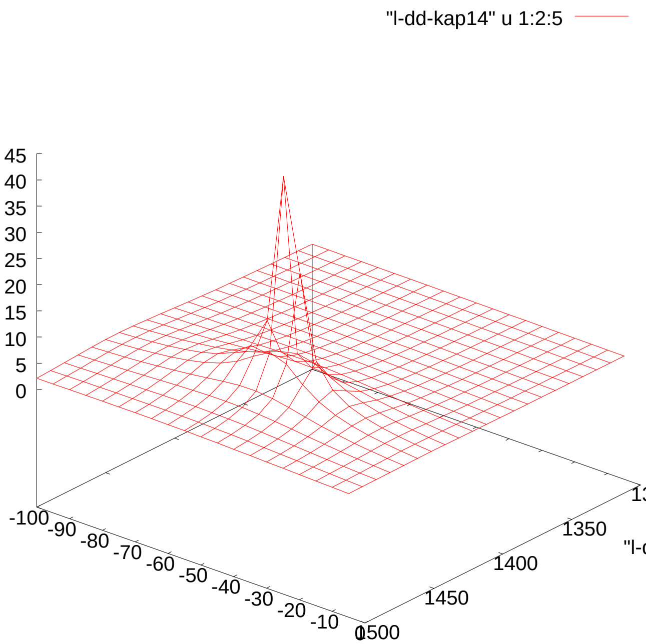


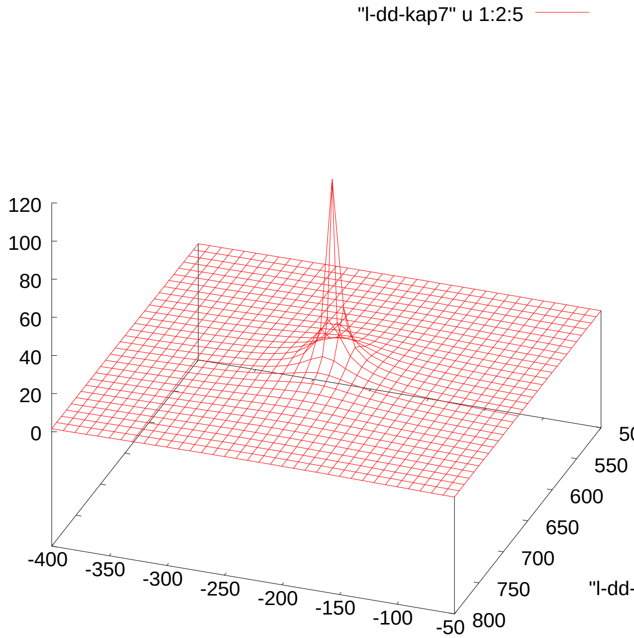


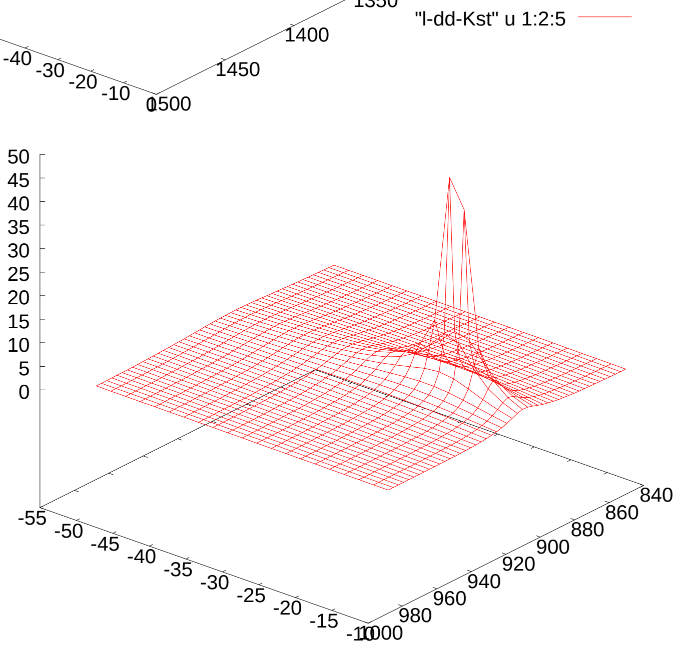


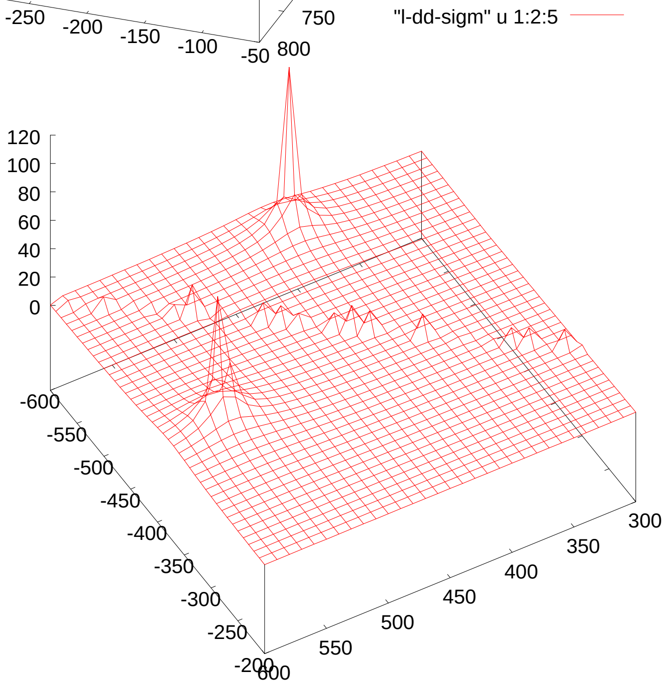


Resonances results









Resonances

	Exp. Data (PDG)	Monopole
$a_0(980)$	[984,-(25÷50)]	$[860, -20]$
$f_0(980)$	$[980, -(20 \div 50)]$	$[980, -70]$
$f_2(1270)$	$[1275(1.2), -92(2)]$	$[1280, -100]$
$\kappa(1430)$	$[1412(6), -147(12)]$	$[1440, -50]$
$\kappa(700)$		$[640, -200]$
$K^*(892)$	$[892, -25]$	$[910, -20]$
$\phi(1020)$	$[1019, -2]$	$[1020, -2]$
$\rho(770)$	$[771, -75]$	$[790, -50]$
$\sigma_1(600)$	$[400 - 1200, -(300 - 500)]$	$[550, -360]$
σ_2		$[410, -550]$

※ $[M, -(\frac{\Gamma}{2})]$

Conclusion

- This calculation are well reproduce the phase shift, cross-section and pole position in the meson-meson interaction by the meson exchange model.
  - $\pi\pi - KK^{bar} - \pi\eta - \eta\eta$
    - $\delta_0^0; \delta_0^1; \delta_1^0; \delta_1^1; \delta_2^0$
    - $\sigma(600), f_0(980), \rho(770), a_0(980), \phi(1020)$
  - $\pi K - \eta K$
    - $\delta_0^{\frac{1}{2}}, \delta_1^{\frac{1}{2}}$
    - $\kappa(700), \kappa(1430), K^*(982)$
- The shown results can prove the suitable effective of meson-exchange model on well-produce the interaction of mesons.
- Exist the $\kappa(700); \sigma(600)$ poles with broad width → experiment???
- **FURTURE PLAN**
  - Refine our model by reasonable bare mass fitting-parameter for ($\delta_0^0; \delta_0^{\frac{1}{2}}, \delta_1^{\frac{1}{2}}$)
  - Calculation with the Gaussian F.F
  - Solve the dynamical 3 body problems to study the existence and properties of the resonances in the hadronic system.

THANK YOU FOR YOUR ATTENTION