Scalar K^{bar} N interaction

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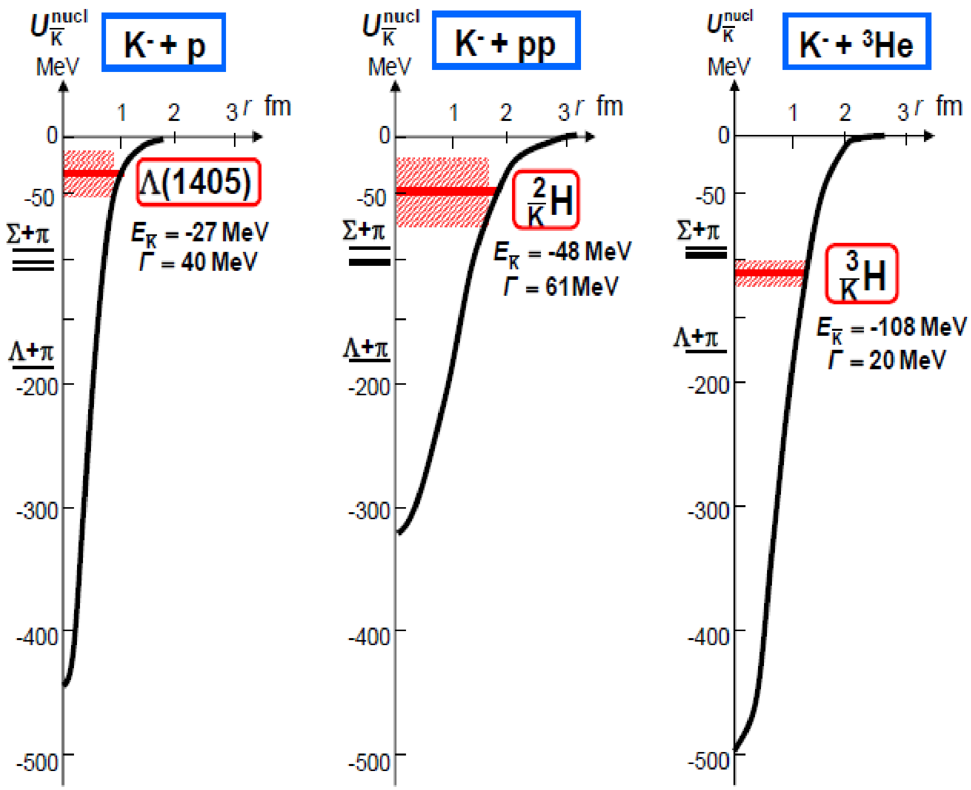
Introduction

Kaon bound state in Nuclei

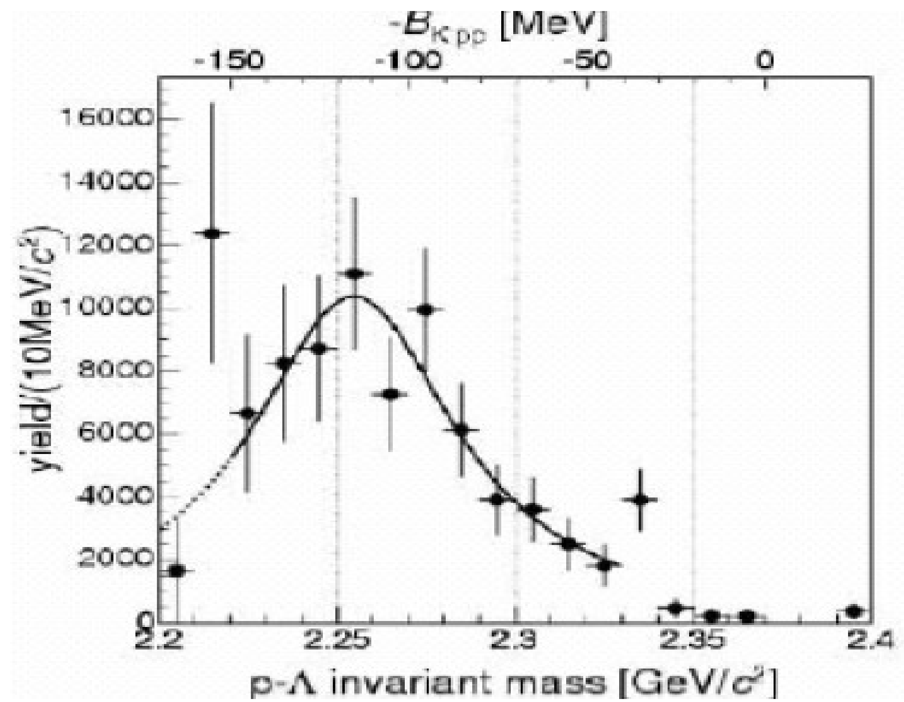
Theoretical study

Y. Akaishi and T. Yamazaki
Phys. Rev. C65 (2002) 044005



Experimental study

FINUDA collaboration
Phys. Rev. Lett. 94 (2005) 212303



$B_{Kpp} = 115\mathrm{MeV} \quad \Gamma = 67\mathrm{MeV}$

What is the role of keon in nuclei ?

Introduction

$\Lambda(1405)$ ⟺ K^{bar} N system

Hadron exchange model

Julich model

Pole graph around 1.4GeV is not resonable

⇩

Phenomenological potential

Deeply bound K^{bar} system

Quark model

Not genuine 3q state

Lattice QCD

Not genuine 3q state

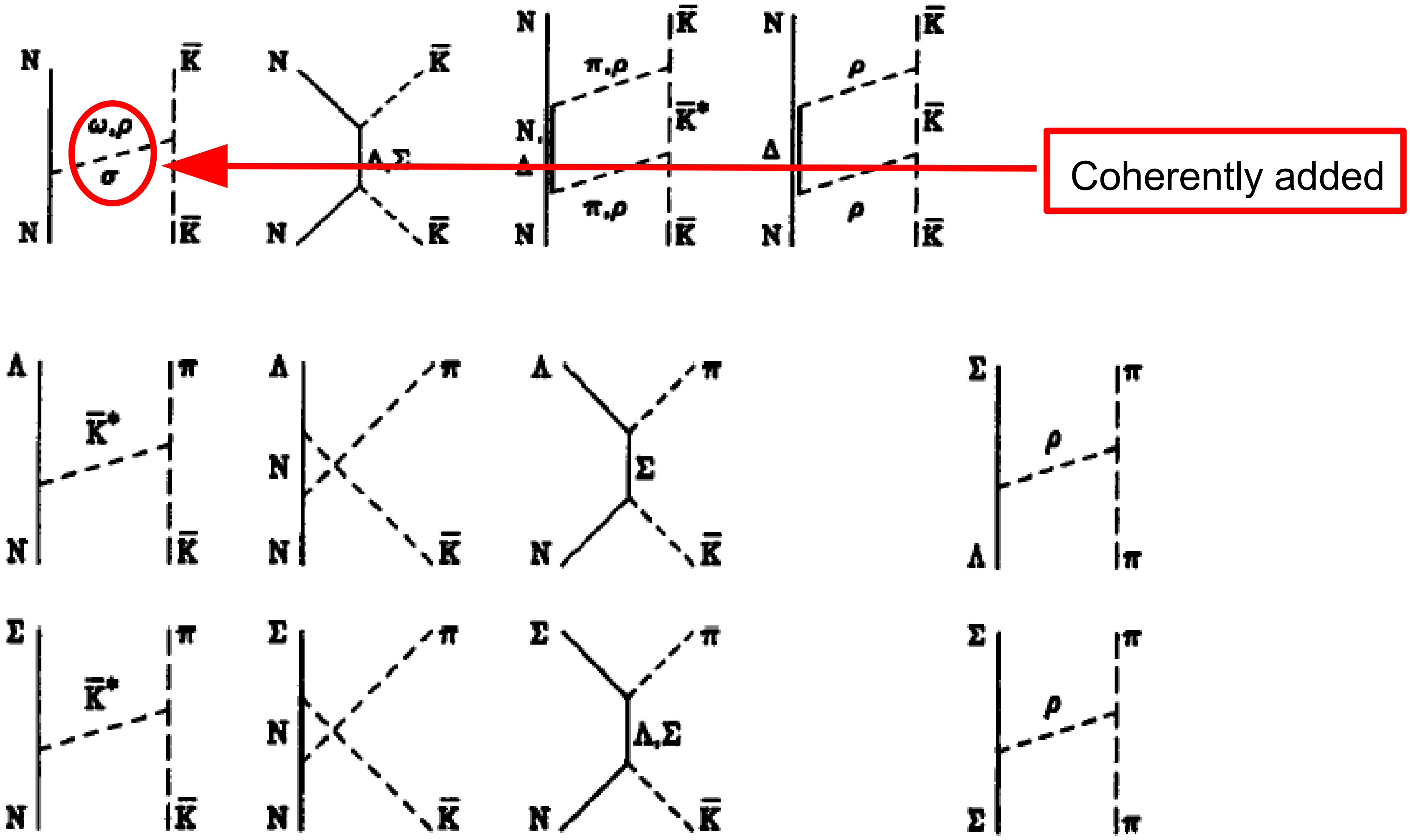
Chiral Unitary Method

Two pole structure

The Julich K^{bar} N interaction

A.Muller-Groeling-NPA513(1990)557

Model



The Julich K^{bar} N interaction

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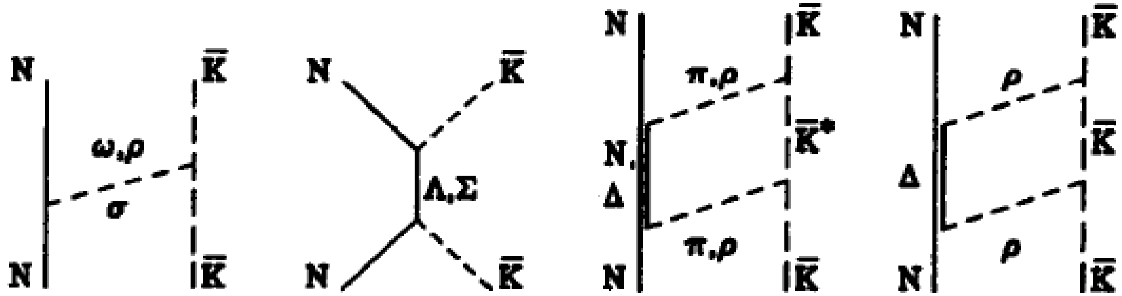
Model



Process	Exch. part
NK̄ → NK̄	σ
	σ_0
	ω
	ρ
	Λ
	Σ

$T = V + VGT$ ⇒ Observables

- The V is constructed by relatively lower-order diagrams which are shown in above.

- The scalar coupling is adjusted by the empirical data

- Phenomenological short-ranged repulsion (σ_0) is needed in KN system

- σ_0 contribution is weak but still repulsive in K^{bar} N system

Mixture of positive and negative G-parity parts

The Julich K^{bar} N interaction

A.Muller-Groeling-NPA513(1990)557

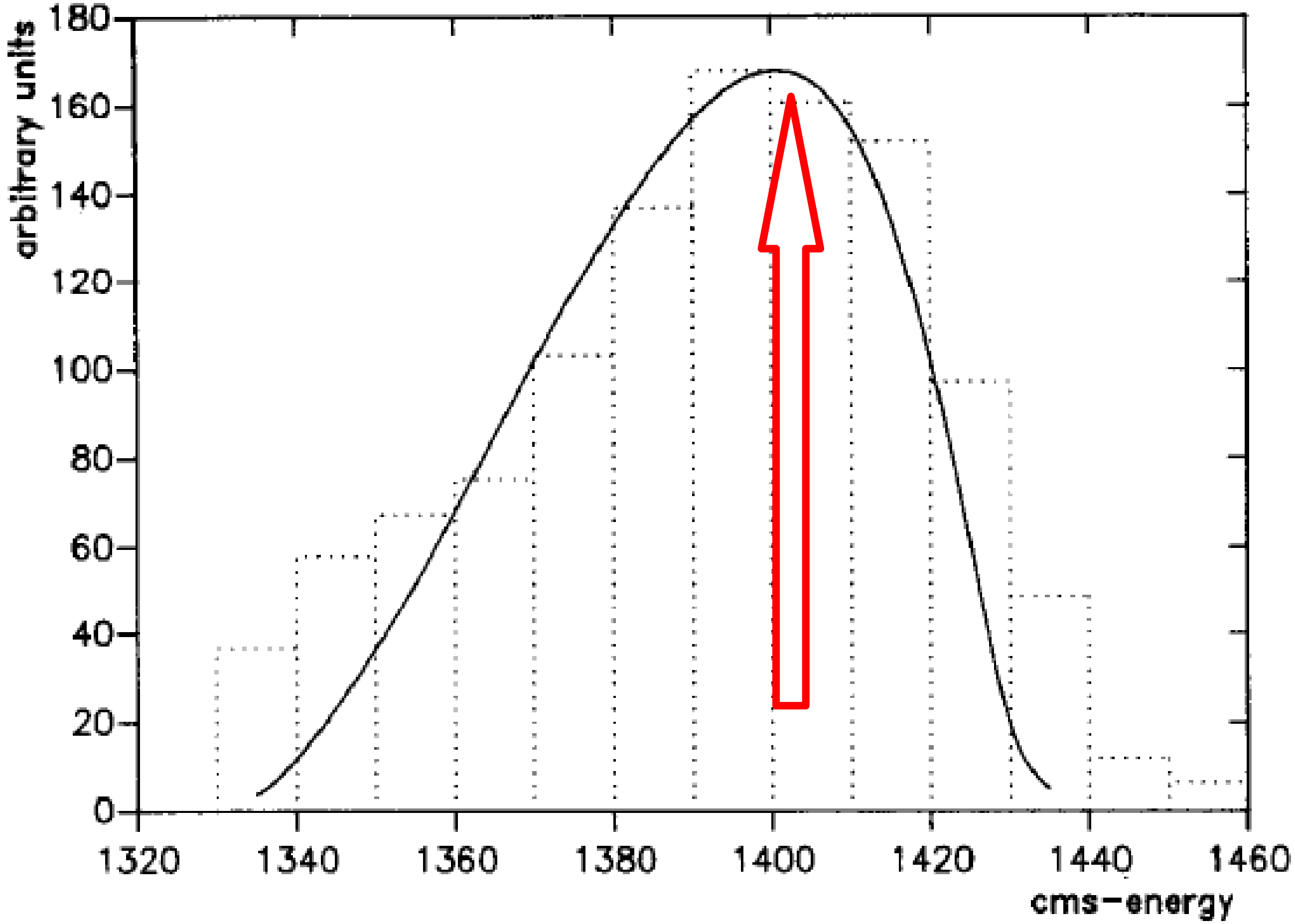


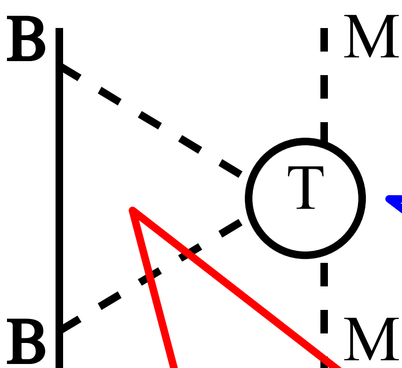
Fig. 4. The $\Lambda(1405)$ mass spectrum. We compare the prediction of model I in the diagonal $\Sigma\pi$ channel, i.e., the quantity $|T_{\Sigma\pi}|^2 q_{c.m.}$, with experimental data taken from ref. [31]).

Λ(1405) state can be seen at proper position without the pole graph in V.

Scalar K^{bar} N potential by correlated two mesons

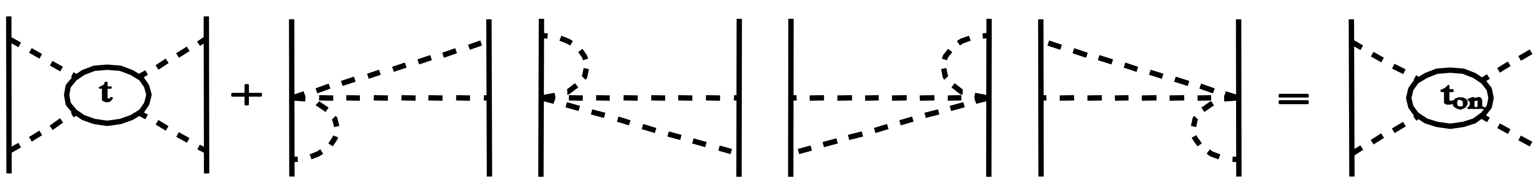
What is the repulsive interaction in the scalar channel ?

Method



- T-matrix of meson-meson scattering calculated by the chiral unitary method.
- It reproduces the meson-meson phase shift up to 1.2GeV quite well.

- Triangle scalar loop contribution



Cancellation mechanism for off-shell part of meson-meson amplitude

•(E Oset, H Toki, M Mizobe, and T T Takahashi PTP103 (2000) 351).

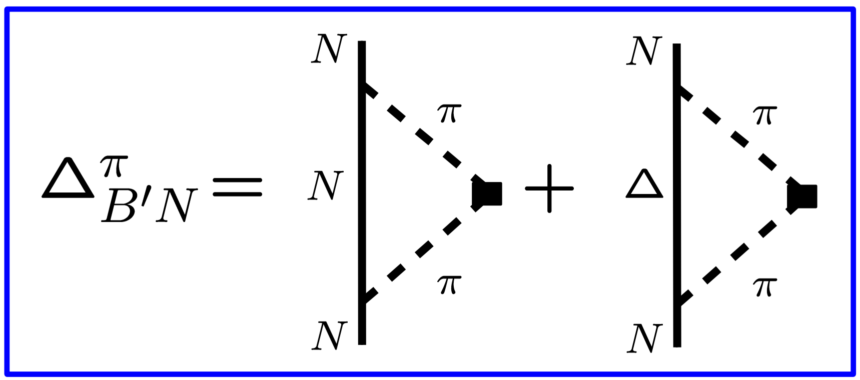
Diagrams of two-meson triangle loop

Meson-baryon (Octet) interaction

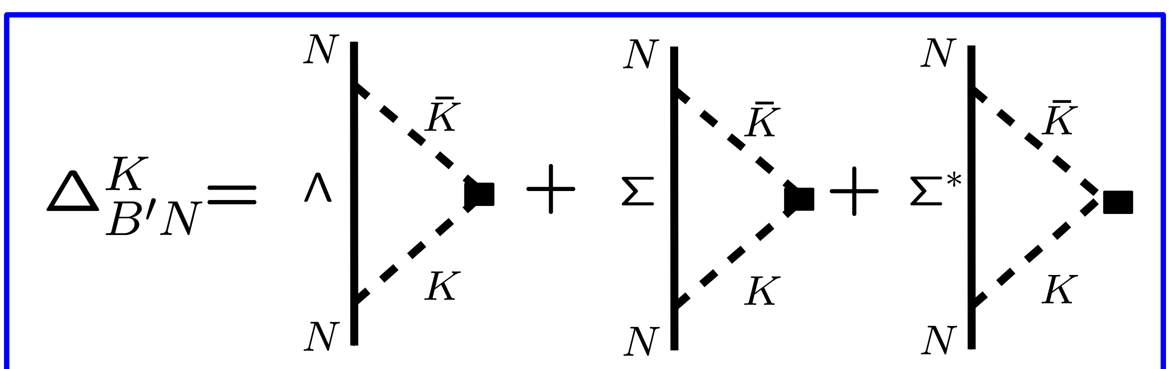
$$\mathcal{L}^B = \frac{D+F}{\sqrt{2}f_\pi}\langle \bar{B}\gamma_5\gamma^\mu\partial_\mu\Phi B\rangle + \frac{D-F}{\sqrt{2}f_\pi}\langle \bar{B}\gamma_5\gamma^\mu B\partial_\mu\Phi\rangle$$

Meson-baryon (Decuplet) interaction

$$\mathcal{L} = \frac{\sqrt{2}}{f_\pi}\mathcal{C}\sum_{a,b,c,d,e}^{1\sim 3}\epsilon^{abc}\left(-(\bar{T}_{ade}\Phi^d_b B^e_c)\vec{S}\cdot\vec{q} + (\bar{B}^c_e\Phi^b_d T_{ade})\vec{S}^\dagger\cdot\vec{q}\right)$$



Pion loop contributions



Kaon loop contributions

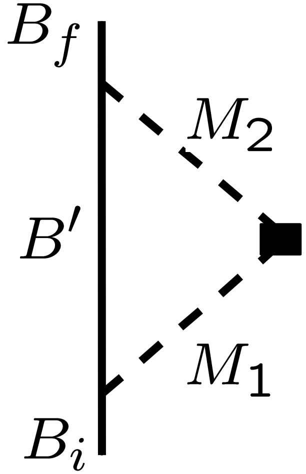
Triangle scalar loop contribution

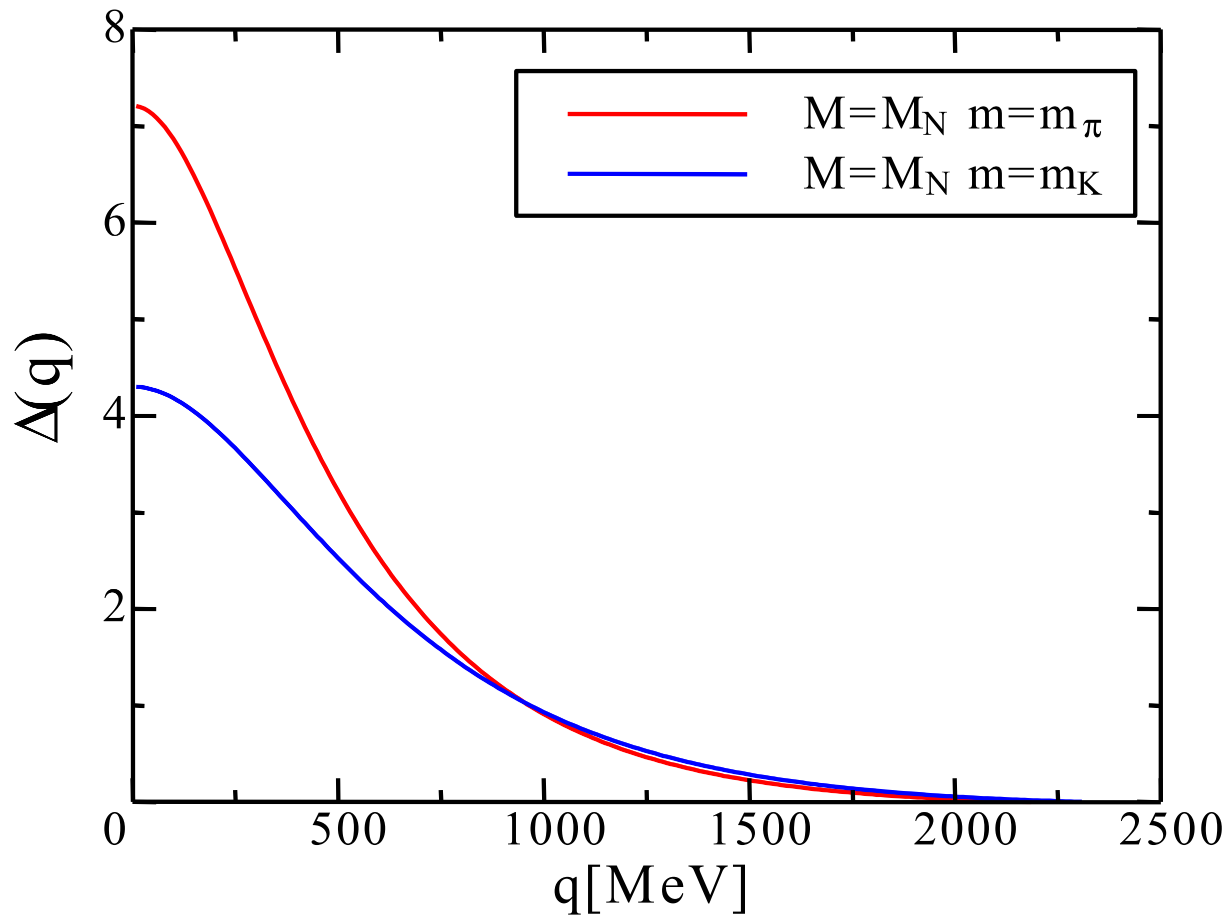
$$\Delta^{M}_{B'B}(q) = \int \frac{d^3p}{(2\pi)^3}\frac{M'}{E}\frac{(\vec{p}+\vec{q})\cdot\vec{p}}{2\omega\omega'(\omega+\omega')}\frac{\omega+\omega'+E-M}{(\omega+E-M)(\omega'+E-M)}$$

$$E = \sqrt{\vec{p}^2 + {M'}^2}$$

$$\omega = \sqrt{m_1^2 + \vec{p}^2}$$

$$\omega' = \sqrt{m_2^2 + (\vec{p}+\vec{q})^2}$$





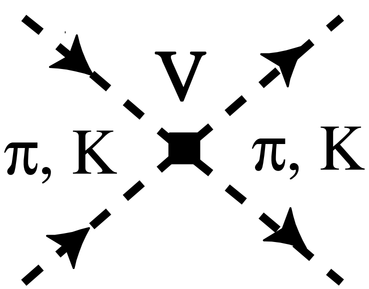
The contribution of the heavy meson loop is suppressed in the small momentum region.

Two meson amplitude in scalar channel

Chiral Lagrangean for meson-meson interaction

$$\mathcal{L}_2 = \frac{1}{6f_\pi^2}\langle \Phi\partial_\mu\Phi\Phi\partial_\mu\Phi - \Phi\Phi\partial_\mu\Phi\partial_\mu\Phi\rangle + \frac{1}{12f_\pi^2}\left\langle M\Phi^4\right\rangle$$

Tree level amplitudes of meson-meson scattering



$$V^{I=0}_{\pi\pi\to\pi\pi} = -\frac{2s-m_\pi^2}{2f_\pi^2} + \frac{1}{3f_\pi^2}\sum_i (p_i^2 - m_i^2)$$

$$V^{I=0}_{K\bar{K}\to K\bar{K}} = -\frac{3s}{4f_\pi^2} + \frac{1}{4f_\pi^2}\sum_i (p_i^2 - m_i^2)$$

$$V^{I=0}_{\pi\pi\to K\bar{K}} = -\frac{\sqrt{3}s}{4f_\pi^2} + \frac{1}{4\sqrt{3}f_\pi^2}\sum_i (p_i^2 - m_i^2)$$

We can separate the off-shell part of amplitudes

Unitarization of the amplitude

Using the tree level interaction, V, as input, we solve the L-S type equation

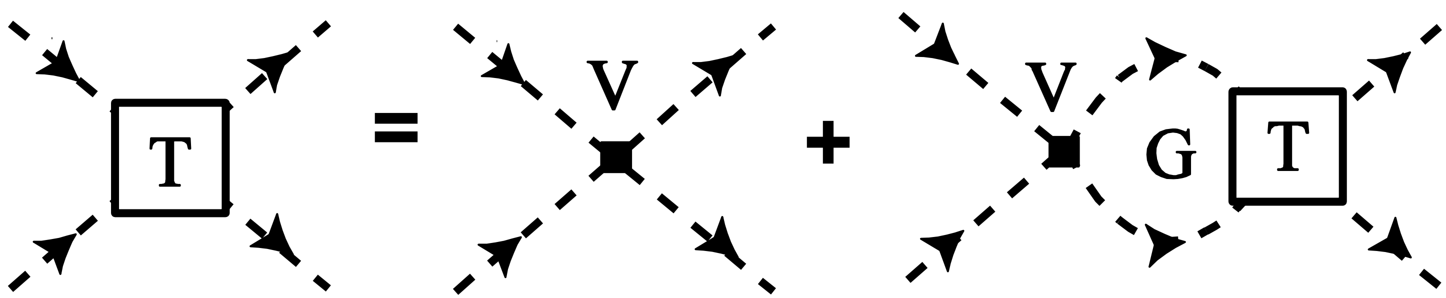
$$T = V + VGT = \frac{1}{1 - VG} V$$

The G is the meson-meson loop function

$$G(s) = \int_0^{q_{\rm max}} \frac{q^2 dq}{(2\pi)^2} \frac{\omega_1 + \omega_2}{\omega_1 \omega_2 [s - (\omega_1 + \omega_2)^2 + i\epsilon]}$$

$$q_{\rm max} = 1.0 \rm GeV$$

(The off-shell part of interaction gives the renormalization of physical values.)



J A Oller and E Oset, Nucl Phys A620 (1997) 438
J A Oller E Oset and J R Pelaez Phys Rev D59 (1999) 074001

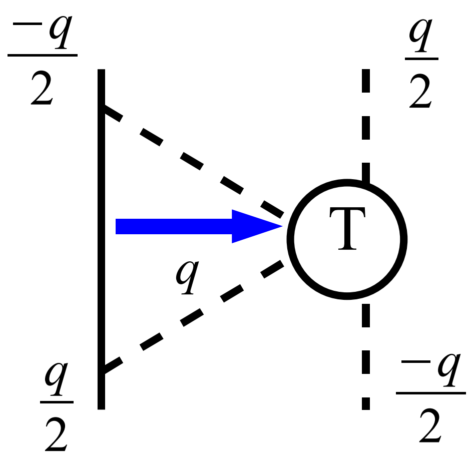
Correlated two-meson potential

$$V^{Cor}_{KN}(q) = \frac{1}{\sqrt{2\omega}\sqrt{2\omega'}} \sum_i \Delta^i_N \, T_{i\to KK}(-q^2)$$

Triangle loop contribution

Meson scattering amplitude

Kinematics



Momentum transfer : q

Energy transfer : 0

In this frame,

$$\omega = \sqrt{\left(\frac{q}{2}\right)^2 + m_K^2} = \sqrt{\left(\frac{-q}{2}\right)^2 + m_K^2} = \omega'$$

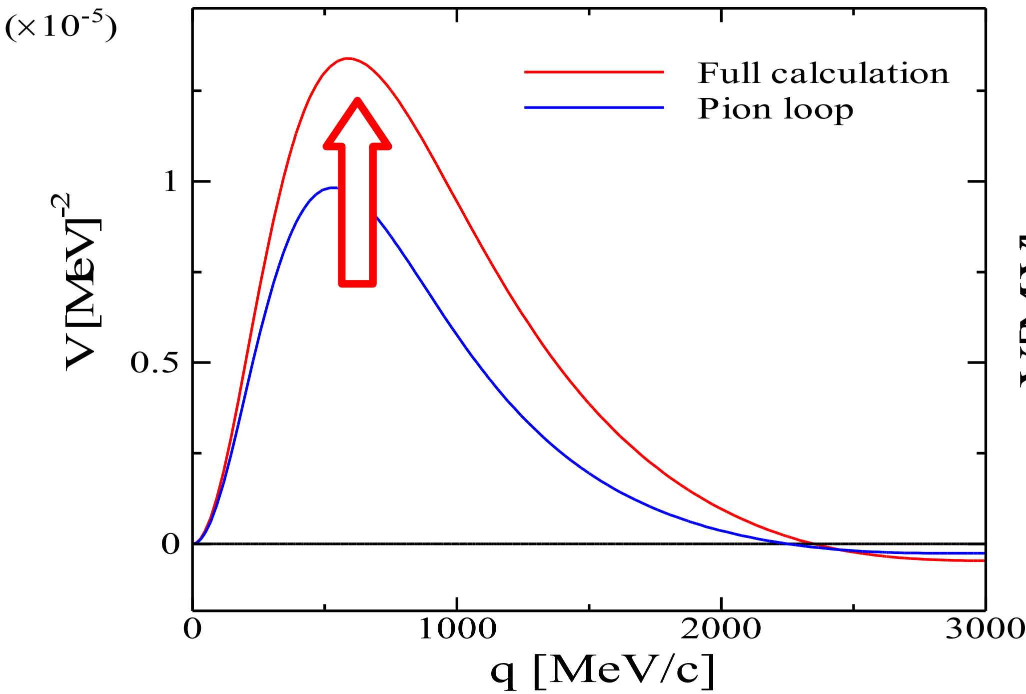
Approximation

$$E_N = \sqrt{\left(\frac{q}{2}\right)^2 + M_N^2} \approx M_N$$

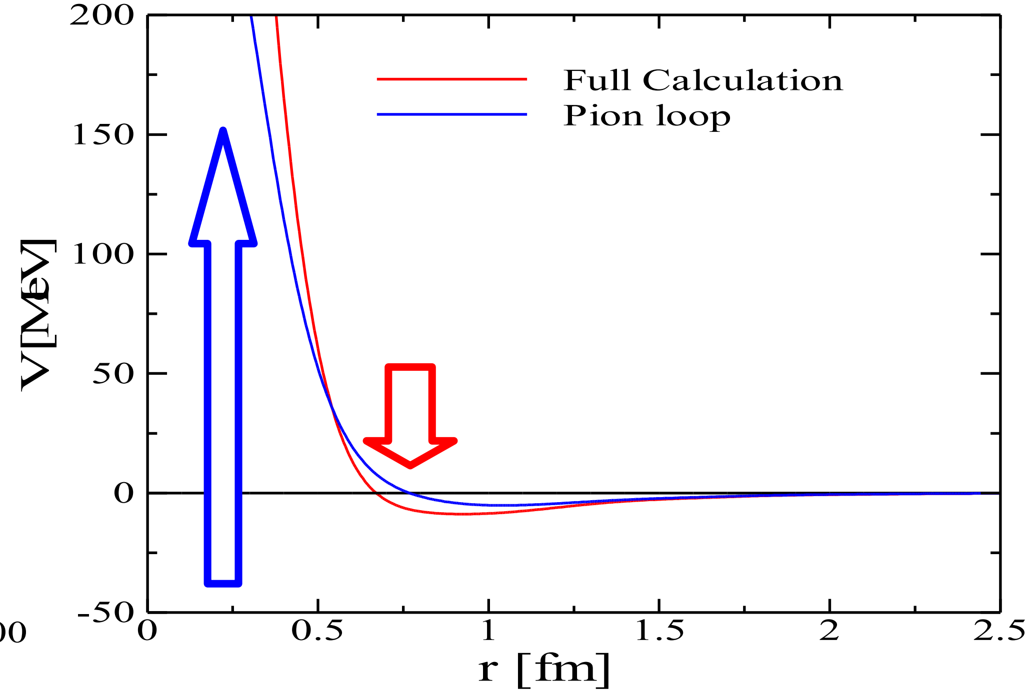
Static baryon approximation

Results

Kbar N potential in momentum space



Kbar N potential in configuration space



- Peak around 700MeV
- Relatively weak attraction at the medium range
- Strong repulsion at the short range region
- Large kaon loop contribution was found
- Strong attraction is generated mainly by the ρ and ω exchange potential

Summaries and conclusions

- I have calculated the correlated two-meson exchange potential for K^{bar} N system.
- In my estimation the correlated two meson potential generates a strong repulsion at the short range region.
- This contribution has the positive G-parity, so that it makes the same contribution in KN system.
- This is a candidate of the short-ranged repulsion which was needed to reproduce the empirical KN scattering data at high energy.

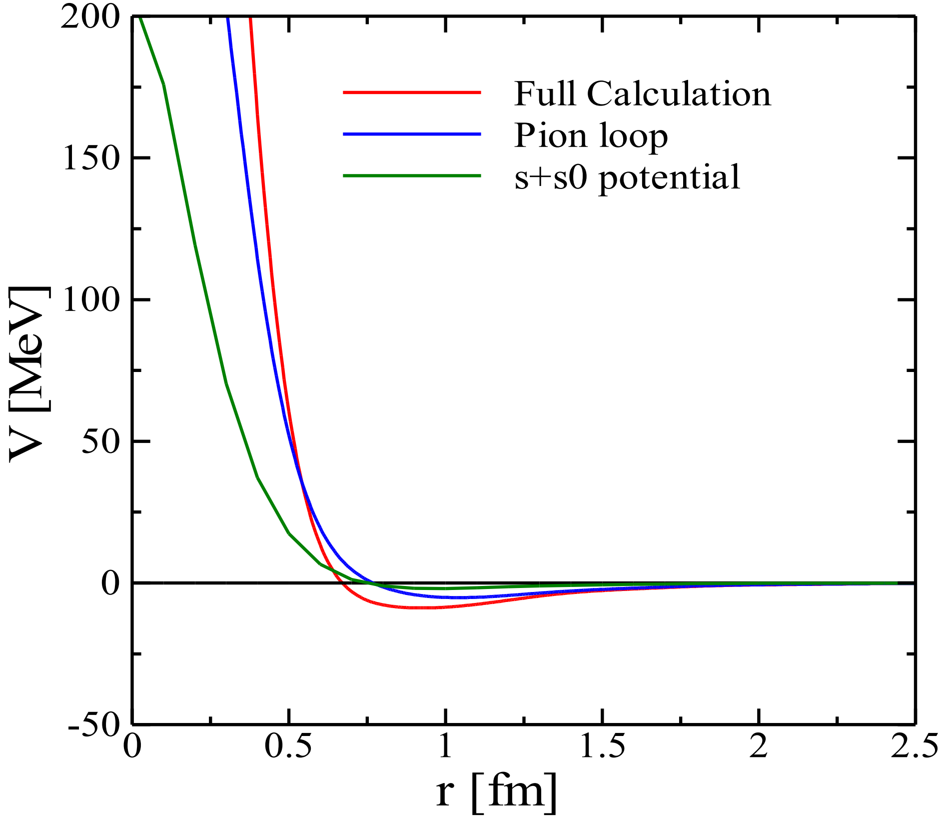
Future plans

- Other contributions to the scalar channel
- What about the negative G-parity part ?
- Construction of the K^{bar} N potential by the hadron exchange picture

K^{bar} N potential

Scalar K^{bar} N potential by Julich (σ and σ_0) model

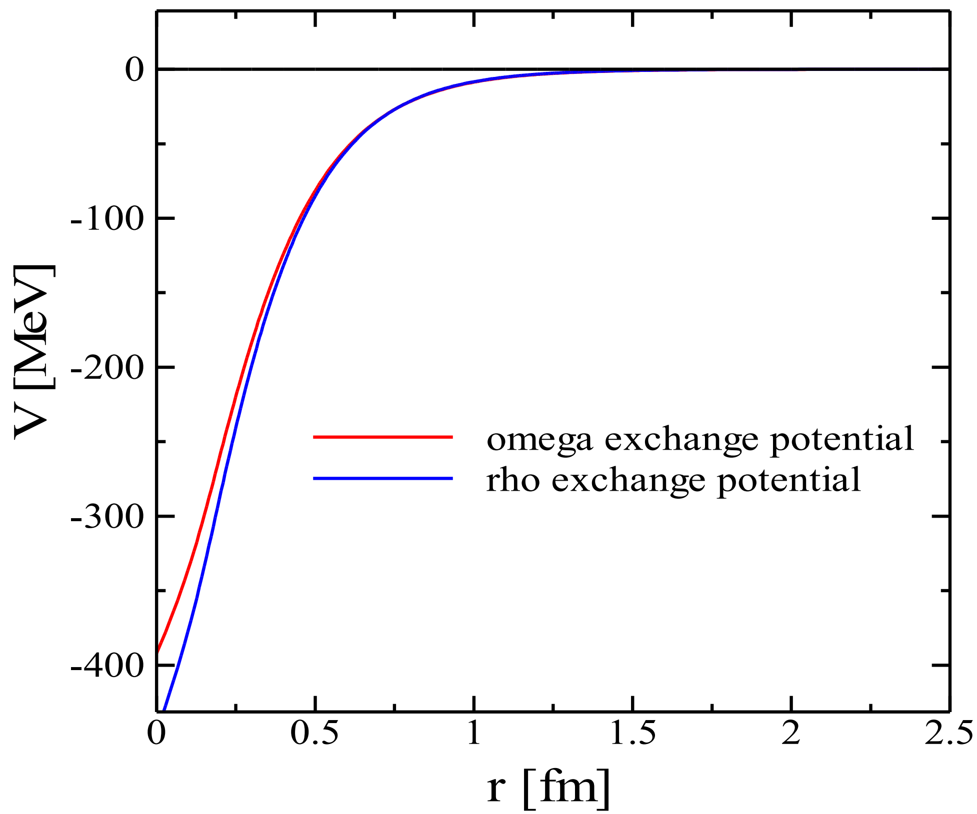
$$V^S(q) = \frac{1}{2\omega_K}\frac{g_{\sigma_0} m_K}{q^2 + m_{\sigma_0}^2} - \frac{1}{2\omega_K}\frac{g_\sigma m_K}{q^2 + m_\sigma^2}$$



The full result has stronger repulsion than the σ_0 contribution

The K^{bar} N potential by vector meson exchange

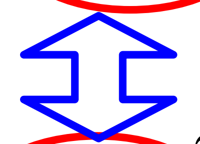
In the same approximations



$$V^V(q) = \frac{1}{2\omega}\left(\frac{-2\omega g' f}{q^2 + m_V^2} + 2\omega \frac{g' g + g' f}{q^2 + m_V^2} \right)$$

Near the threshold

$$U \approx -0.883 \frac{2m_K}{f^2}$$



$$U^{WT} = -0.75 \frac{2m_K}{f^2}$$

- The ρ and ω meson generate a strong attractionin K^{bar} N system
- The ρ and ω meson have large cancellation in K N system