$\bar{K}NN-\pi YN$ 系, $J^{\pi}=1^{-}$ の状態について

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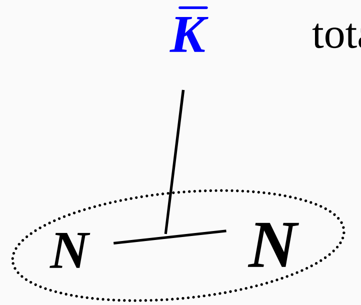
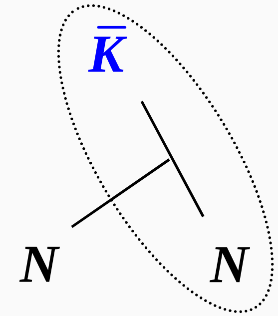
$\pi Y N - K^- pp$



total isospin

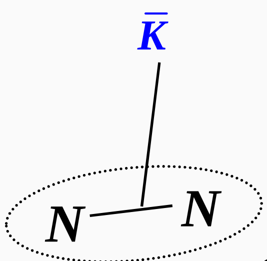
$I = \frac{1}{2}$



$\bar{K}\,(NN)$, $\quad i_{NN} = 1$ or 0

$(\bar{K}N)\,N$, $\quad i_{KN} = 0$

$$\left\langle \underset{\bar{K}}{\tfrac{1}{2}} ,\ \left(\underset{N}{\tfrac{1}{2}}\ \underset{N}{\tfrac{1}{2}}\right) i_{NN} \ \middle|\ \left(\underset{\bar{K}}{\tfrac{1}{2}}\ \underset{N}{\tfrac{1}{2}}\right)^{i_{KN}}_{0} ,\ \underset{N}{\tfrac{1}{2}} \right\rangle = \begin{cases} \sqrt{3} & (i_{NN} = 1) \\ 1 & (i_{NN} = 0) \end{cases}$$



${}^1S_0$

$(i = 1,\ j = 0)\quad J^\pi = 0^-$

$(i = 0,\ j = 1)\quad J^\pi = 1^-$

${}^3S_1 - {}^3D_1$

$J^\pi = 1^-$ の状態がどの程度引力的か？

$\Sigma N - \Lambda N,\ j = 1$ $\quad \Sigma N$ しきい値近傍に pole があることにも興味

$\bar{K}NN - \pi YN$

2変数のFaddeev方程式 → 2体相互作用は分離型に限定されない

Realistic な NN interaction

Outline

(1) formalism

(2) テスト計算

$\bar{K}N - \pi Y$ coupling を切って

$\bar{K}NN$ bound state $J^{\pi} = 0^{-}\ (NN\ {}^{1}S_{0})$, $J^{\pi} = 1^{-}\ (NN\ {}^{3}S_{1} - {}^{3}D_{1})$ の違いを見る

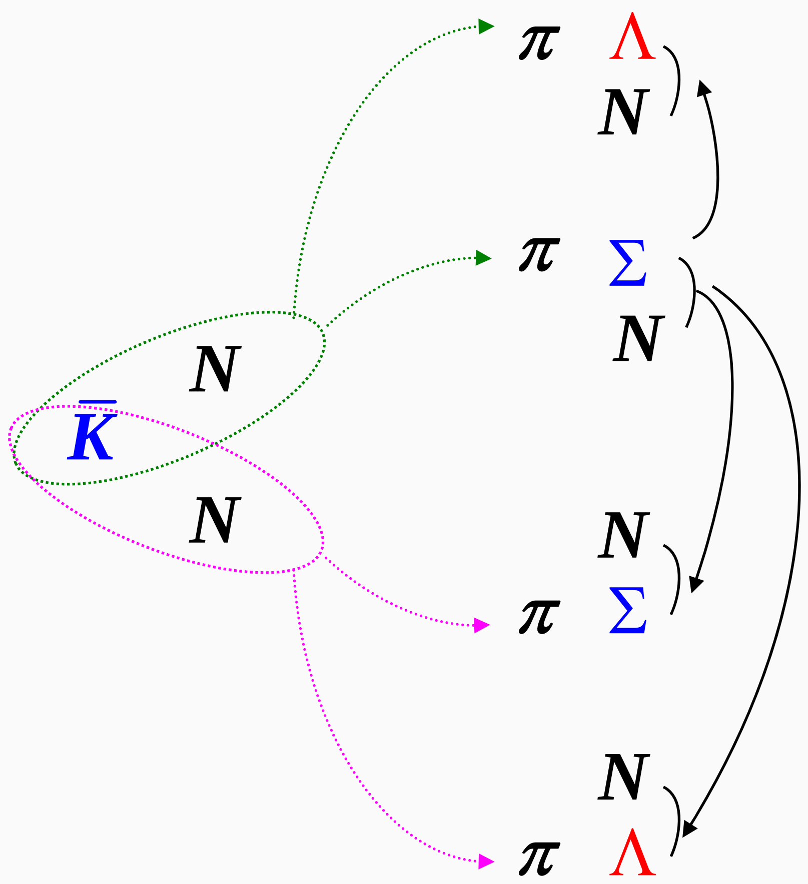
相互作用

NN … Nijmegen93

$\bar{K}N - \pi Y$ … Ikeda, Sato

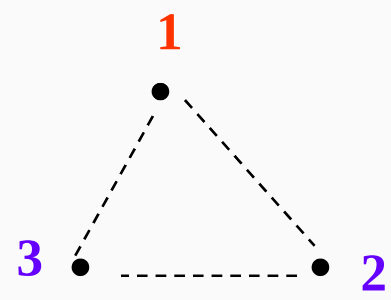
$\bar{K}NN - \pi\Sigma N\,(-\pi\Lambda N)$ 系の定式化

反対称化



$$H = H_0 + V$$

$$= H_0 + V_{12} + V_{13} + V_{23}$$



1 --- meson

2,3 --- baryons

$$P_{23}H = HP_{23}$$

$$(H_0 + V)\, Y = E\, Y$$

$$\searrow \quad Y = G_0 V Y = G_0 (V_{12} + V_{13} + V_{23}) Y$$

$$\text{コ} \quad y^{(3)} + y^{(2)} + y^{(1)}$$

$$y^{(1)} \,\text{コ}\, G_0 V_{23} Y = G_0 V_{23} (y^{(1)} + y^{(2)} + y^{(3)})$$

$y^{(1)}$ について解くと

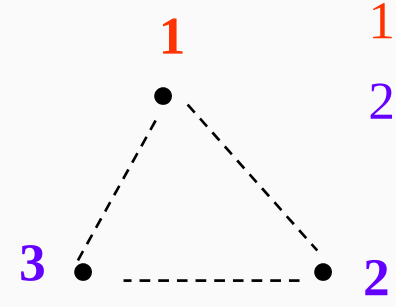
$$y^{(1)} \,\text{コ}\, G_0 t_{23} (y^{(2)} + y^{(3)})$$

同様に →

$$\begin{cases} y^{(1)} \,\text{コ}\, G_0 t_{23} (y^{(2)} + y^{(3)}) \\ y^{(2)} \,\text{コ}\, G_0 t_{13} (y^{(1)} + y^{(3)}) \\ y^{(3)} \,\text{コ}\, G_0 t_{12} (y^{(1)} + y^{(2)}) \end{cases}$$

Faddeev 方程式

$$\begin{cases} y^{(1)} \,\text{コ}\, G_0\, t_{23} \left(y^{(2)} + y^{(3)} \right) \\ y^{(2)} \,\text{コ}\, G_0\, t_{13} \left(y^{(1)} + y^{(3)} \right) \\ y^{(3)} \,\text{コ}\, G_0\, t_{12} \left(y^{(1)} + y^{(2)} \right) \end{cases}$$



1 --- meson

2,3 --- baryons

$$\Upsilon = y^{(1)} + y^{(2)} + y^{(3)}$$

反対称化

$$P_{23}\, \Upsilon = -\, \Upsilon$$ より $$y^{(1)} = -\, y^{(1)}$$

$$P_{23} y^{(2)} = -\, y^{(3)}$$

$$\begin{cases} y^{(1)} \,\text{コ}\, G_0\, t_{23} \left(1 - P_{23} \right) y^{(2)} \\ y^{(2)} \,\text{コ}\, G_0\, t_{13} \left(y^{(1)} - P_{23} y^{(2)} \right) \end{cases}$$

$\bar{K}NN - \pi\Sigma N$ 系

1(meson), 2,(baryon) 3(baryon)の状態として

$$|\text{momenta, spins, isospins}\rangle\,|\text{particle labels}\rangle$$

完全系

$$|\underset{1\,2\,3}{\bar{K}NN}\rangle\langle\bar{K}NN| + |\pi\underset{2\,3}{\Sigma N}\rangle\langle\pi\underset{2\,3}{\Sigma N}| + |\pi\underset{2\,3}{N\Sigma}\rangle\langle\pi\underset{2\,3}{N\Sigma}| = 1$$

反対称化・・ partile label の空間まで含めて $P_{23}\Psi = -\Psi$ とする

(Glöckle, Miyagawa, Few-body Systems 30, 241)

例えば $\psi^{(1)} = G_0 V_{23}\Psi$

$$\langle\pi\Sigma N|\psi^{(23)}\rangle = G_0(\pi\Sigma N)\{\langle\pi\Sigma N|V_{23}|\pi\Sigma N\rangle\langle\pi\Sigma N| + \langle\pi\Sigma N|V_{23}|\pi N\Sigma\rangle\langle\pi N\Sigma|\Psi\rangle\}$$

$\langle\pi N\Sigma|\Psi\rangle \rightarrow -\langle\pi\Sigma N|P_{23}\Psi\rangle$

$$= G_0(\pi\Sigma N)\{(V_{\Sigma N,\Sigma N}(23) - V_{\Sigma N,N\Sigma}(23)P_{23})\langle\pi\Sigma N|\ \ \}$$

direct　　exchange

結局，$\bar{K}NN$ 系 ２個，$\pi\Sigma N$ 系 ３個の Faddeev amplitude

が couple した式となる

1 --- meson

2,3 --- baryons

$$y^{(1)}_{\bar{K}NN} = G_0(\bar{K}NN)\, T_{NN}(23)\,(1 - P_{23})\, y^{(2)}_{\bar{K}NN}$$

$$y^{(3)}_{\bar{K}NN} = G_0(\bar{K}NN)\, \{\, T_{\bar{K}N,\bar{K}N}(12)\,(-P_{23} y^{(3)}_{\bar{K}NN} + y^{(1)}_{\bar{K}NN}) + T_{\bar{K}N,p\mathrm{S}}(12)\,(y^{(2)}_{p\mathrm{S}N} + y^{(1)}_{p\mathrm{S}N}) \,\}$$

$$y^{(3)}_{p\mathrm{S}N} = G_0(p\mathrm{S}N)\, \{\, T_{p\mathrm{S},\bar{K}N}(12)\,(-P_{23} y^{(3)}_{\bar{K}NN} + y^{(1)}_{\bar{K}NN}) + T_{p\mathrm{S},p\mathrm{S}}(12)\,(y^{(2)}_{p\mathrm{S}N} + y^{(1)}_{p\mathrm{S}N}) \,\}$$

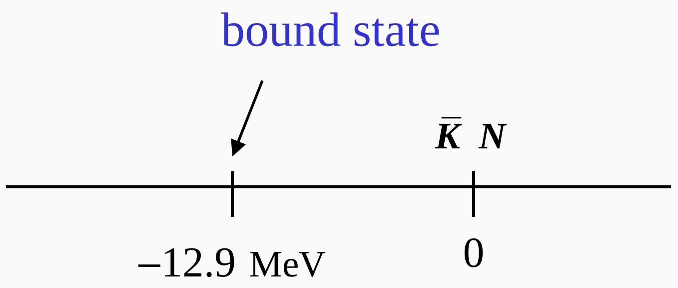
$$y^{(1)}_{p\mathrm{S}N} = G_0(p\mathrm{S}N)\, \{\, T_{\mathrm{S}N,\mathrm{S}N}(23)\,(y^{(3)}_{p\mathrm{S}N} + y^{(2)}_{p\mathrm{S}N}) \,\}$$

$$y^{(2)}_{p\mathrm{S}N} = G_0(p\mathrm{S}N)\, T_{pN}(13)\,(y^{(3)}_{p\mathrm{S}N} + y^{(1)}_{p\mathrm{S}N})$$

$$V^{tot}_{\mathrm{S}N,\mathrm{S}N}(23) = V_{\mathrm{S}N,\mathrm{S}N}(23) - V_{\mathrm{S}N,N\mathrm{S}}(23)\, P_{23}$$

（2） テスト計算

$$V_{M-B} = \begin{pmatrix} V_{\bar{K}N,\bar{K}N} & V_{\bar{K}N,pY} \\ V_{pY,\bar{K}N} & V_{pY,pY} \end{pmatrix}$$



Ikeda, Sato, Phys. Rev.C76, 035203

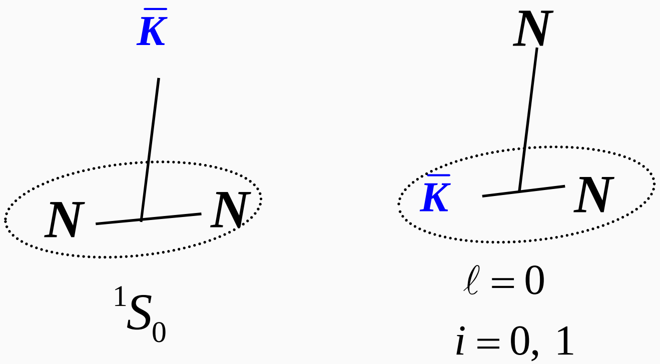
のモデル(a), 分離型 を使って

$i = 0$ $a_{KN} = -1.70 + 0.68i$ (fm)

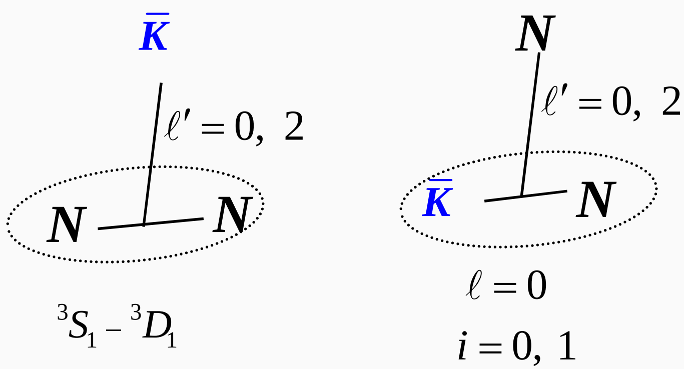
resonance $1420 - 30.1\,i$ (MeV)

$i = 1$ $a_{KN} = 0.72 + 0.59i$ (fm)

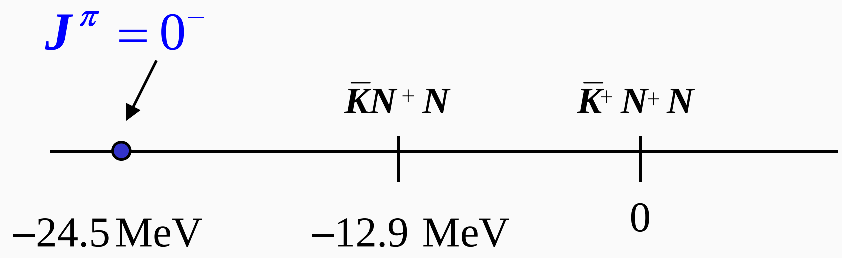
$J^{\pi} = 0^{-}$



$J^{\pi} = 1^{-}$



bound state



$J^{\pi} = 1^{-}$ は束縛せず

$\eta(-\mathbf{14}\,\mathrm{MeV}) = \mathbf{0.76}$

$$h(\boldsymbol{E})\psi = \boldsymbol{K}(\boldsymbol{E})\psi$$

$h(\boldsymbol{E}) = \mathbf{1}$ で bound state

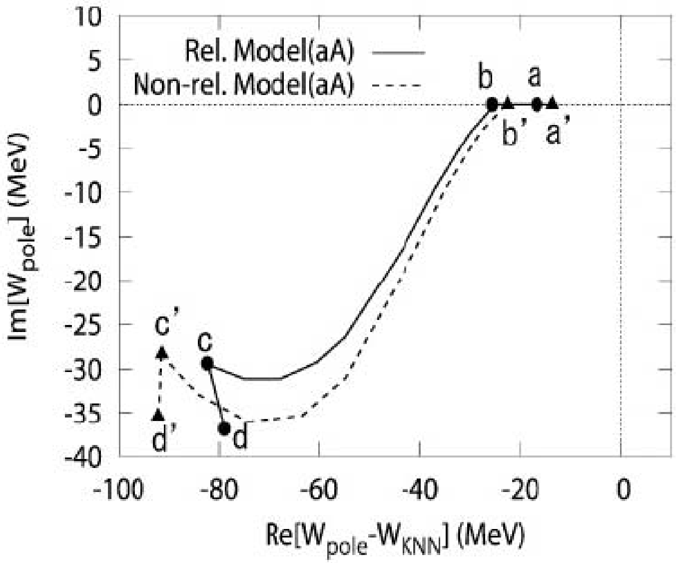


FIG. 9. Pole trajectories of the $\bar{K}NN$-πYN scattering amplitude for the $J^\pi = 0^-$ and $I = 1/2$ state. Filled circles (filled triangles) show the results of the relativistic (nonrelativistic) model (aA) for different steps in the analysis, as explained in the text. Here $W_{KNN} = m_K + 2m_N$.

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まとめ

$\bar{K}NN$　2変数のFaddeev方程式を解く

相互作用　$NN \cdots$　Nijmegen93

$\bar{K}N \cdots$　Ikeda, Satoの $\bar{K}N - \pi Y$ coupling を切って

$J^{\pi} = 0^{-}$　-24.5 MeV　に対して

$J^{\pi} = 1^{-}$　は束縛せず

$\eta(-14\,\mathrm{MeV}) = 0.76$