نقش حالت تشدیدی Λ(۱۴۰۵) در تعیین انرژی سیستم $K^{-}pp$

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Λ(1405) resonance

Negative parity baryon resonance (PDG)

Spin S =1/2

Isospin I = 0

Strangeness S = -1

Mass m = 1406 MeV

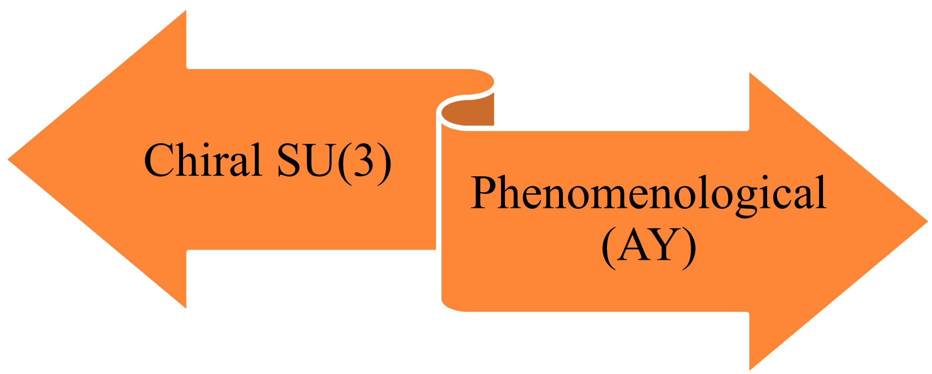
Slightly below the $\bar{\mathrm{K}}\mathrm{N}$ threshold and decays into the $\pi\Sigma, \pi\Lambda$

Theoretically predicted in 1959 Phys. Rev. Lett. **2** (1959) 425

Experimental evidence of this resonance was reported 1961

Invariant mass spectrum of the $\pi\Sigma$ in $K^{-}p \rightarrow \pi\pi\pi\Sigma$ Phys. Rev. Lett. **6** (1961) 698

Nature of Λ(1405)



Λ(1405) in few-body nuclear systems

Λ(1405) is not detectable in direct $\pi\Sigma$ reaction

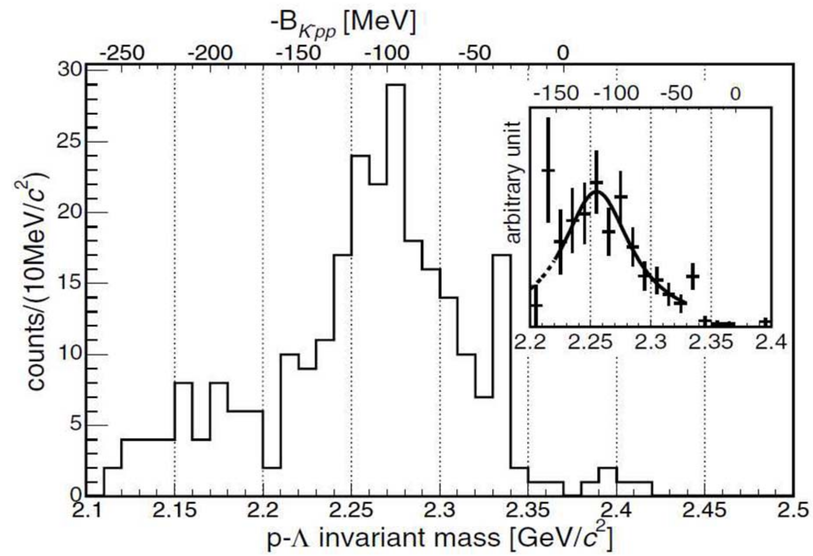
Idea of Λ(1405) as a $\bar{K}N$ quasi-bound state, developed to propose a $\bar{K}NN$ quasi-bound state

modern approach in Ref Phys. Rev. C**65** (2002) 044005

Experimental studies

ΛN spectrum in the Stopped K^- reaction on ^6Li, ^7Li and ^{12}C targets (FINUDA)

B =115 MeV and the width of Γ= 67 MeV



pp→ K^+Λp reaction at 2.85 GeV, a broad peak of the Λp spectrum was found. (DISTO)

B =103 MeV and the width of Γ = 118 MeV

$\bar{K}NN$ quasi-bound state

studied in various theoretical approaches

$\bar{K}NN$ system is bound below the $\bar{K}NN$ break-up threshold with a large width

Choice of the $\bar{K}N$ interaction
- Phenomenological
- Chiral low energy theorem

- energy dependent
- energy independent

Method to solve the three-body system
- Faddeev approach
- Variational approach

Faddeev method

1) Faddeev Yakubovsky

2) Faddeev AGS

$$U_{ij} = \left(1 - \delta_{ij}\right)G_\circ^{-1} + \sum_{k=1}^{3}(1 - \delta_{ik})\, T_k G_\circ U_{kj}$$

T_k and $G_\circ$ are T-matrix and free Green function respectively

$\bar{K}NN - \pi\Sigma N$ → $(\bar{K}, N, N)$, (π, N, Σ), (π, Σ, N) Three particle channels

$$T_i \rightarrow T_i^{\alpha\beta}$$

$$G_\circ \rightarrow G_\circ^{\alpha\beta} = \delta_{\alpha\beta} G_\circ^{\alpha}$$

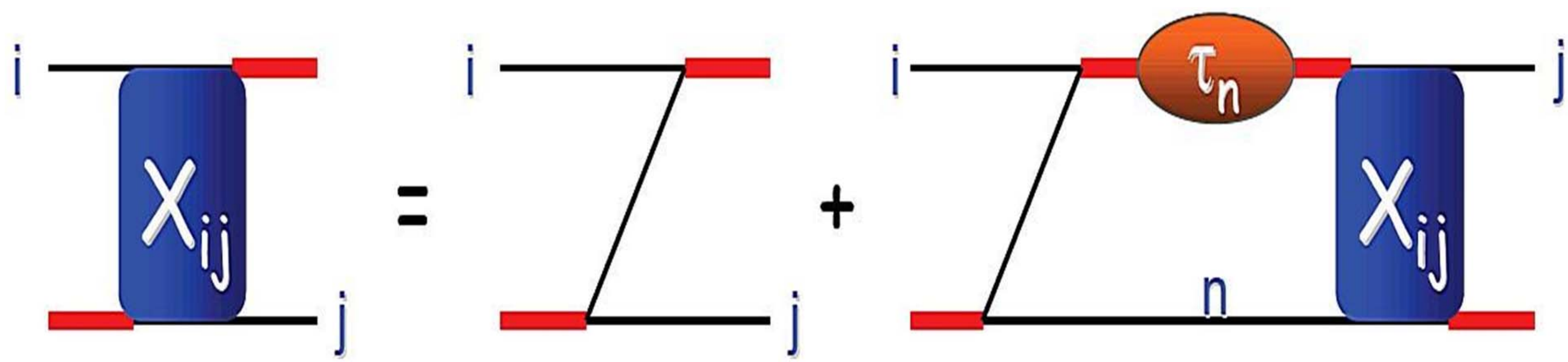
$$T_1 \rightarrow \begin{pmatrix} T_1^{NN} & \circ & \circ \\ \circ & T_1^{\Sigma N} & \circ \\ \circ & \circ & T_1^{\Sigma N} \end{pmatrix} \qquad T_2 \rightarrow \begin{pmatrix} T_2^{KK} & \circ & T_2^{K\pi} \\ \circ & T_2^{\pi N} & \circ \\ T_2^{\pi K} & \circ & T_2^{\pi\pi} \end{pmatrix}$$

$$T_3 \rightarrow \begin{pmatrix} T_3^{KK} & T_3^{K\pi} & \circ \\ T_3^{\pi K} & T_3^{\pi\pi} & \circ \\ \circ & \circ & T_3^{\pi N} \end{pmatrix}$$

$$T_i^{KK}: \quad \bar{K} + N \longrightarrow \bar{K} + N, \qquad T_i^{\pi K}: \quad \bar{K} + N \longrightarrow \pi + \Sigma$$

$$T_i^{K\pi}: \quad \pi + \Sigma \longrightarrow \bar{K} + N, \qquad T_i^{\pi\pi}: \quad \pi + \Sigma \longrightarrow \pi + \Sigma$$

$$X_{ij,I_iI_j}^{\alpha\beta} = \delta_{\alpha\beta} Z_{ij,I_iI_j}^{\alpha} + \sum_{k=1}^{3} \sum_{\gamma=1}^{3} \sum_{I_k} Z_{ik,I_iI_k}^{\alpha} \tau_{k,I_k}^{\alpha\gamma} X_{kj,I_kI_j}^{\gamma\beta}$$

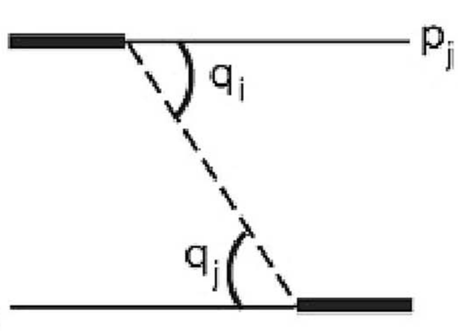


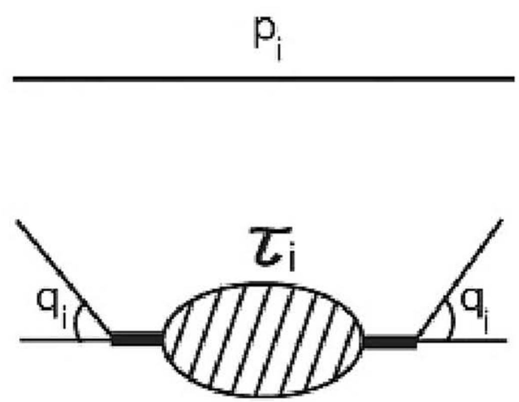
$$X^{\alpha\beta}_{ij,I_iI_j} = \delta_{\alpha\beta} Z^{\alpha}_{ij,I_iI_j} + \sum_{k=1}^{3} \sum_{\gamma=1}^{3} \sum_{I_k} Z^{\alpha}_{ik,I_iI_k} \tau^{\alpha\gamma}_{k,I_k} X^{\gamma\beta}_{kj,I_kI_j}$$

$$X^{\alpha\beta}_{ij,I_iI_j} = \left\langle g^{\alpha}_{i,I_i} \middle| G^{\alpha}_{\circ} U^{\alpha\beta}_{ij,I_iI_j} G^{\beta}_{\circ} \middle| g^{\beta}_{j,I_j} \right\rangle$$

$$Z^{\alpha\beta}_{ij,I_iI_j} = \delta_{\alpha\beta} Z^{\alpha}_{ij,I_iI_j} = \delta_{\alpha\beta}(1-\delta_{ij}) \left\langle g^{\alpha}_{i,I_i} \middle| G^{\alpha}_{\circ} \middle| g^{\beta}_{j,I_j} \right\rangle$$

$$T^{\alpha\beta}_{i,I} = \left| g^{\alpha}_{i,I} \right\rangle \tau^{\alpha\beta}_{i,I} \left\langle g^{\beta}_{i,I} \right| \qquad V^{\alpha\beta}_{i,I} = \left| g^{\alpha}_{i,I} \right\rangle \lambda^{\alpha\beta}_{i,I} \left\langle g^{\beta}_{i,I} \right|$$





$$X^{\alpha\beta}_{ij,I_iI_j} = \delta_{\alpha\beta} Z^{\alpha}_{ij,I_iI_j} + \sum_{k=1}^{3}\sum_{\gamma=1}^{3}\sum_{I_k} Z^{\alpha}_{ik,I_iI_k}\tau^{\alpha\gamma}_{k,I_k}X^{\gamma\beta}_{kj,I_kI_j}$$

$$Z^{\alpha}_{ij,I_iI_j} = -\sum_n \lambda_n Y^{\alpha}_{i,I_i} Y^{\alpha}_{j,I_j}$$

$$X^{\alpha\beta}_{ij,I_iI_j} = \sum_n \frac{\lambda_n}{\lambda_n - 1} Y^{\alpha}_{i,I_i} Y^{\beta}_{j,I_j}$$

$$Y^{\alpha}_{i,I_i} = \frac{1}{\lambda_n(E)} \sum_{k=1}^{3}\sum_{\gamma=1}^{3}\sum_{I_k} Z^{\alpha}_{ik,I_iI_k}\tau^{\alpha\gamma}_{k,I_k}Y^{\gamma}_{k,I_k}$$

Antisymmetrized operators

$Y^{1}_{1,1}$ $\quad$ $Y^{1}_{1,0}$

$Y^{1-}_{2,0} = Y^{1}_{2,0} - Y^{1}_{3,0}$ $\quad$ $Y^{3+}_{2,1} = Y^{3}_{2,1} + Y^{2}_{3,1}$

$Y^{1+}_{2,1} = Y^{1}_{2,1} + Y^{1}_{3,1}$ $\quad$ $Y^{3-}_{2,0} = Y^{3}_{2,0} - Y^{2}_{3,0}$

$Y^{2+}_{2,\frac{1}{2}} = Y^{2}_{2,\frac{1}{2}} + Y^{3}_{3,\frac{1}{2}}$ $\quad$ $Y^{2+}_{1,\frac{1}{2}} = Y^{2}_{1,\frac{1}{2}} + Y^{3}_{1,\frac{1}{2}}$

$Y^{2-}_{2,\frac{3}{2}} = Y^{2}_{2,\frac{3}{2}} - Y^{3}_{3,\frac{3}{2}}$ $\quad$ $Y^{2-}_{1,\frac{3}{2}} = Y^{2}_{1,\frac{3}{2}} - Y^{3}_{1,\frac{3}{2}}$

$\bar{K}N$ interaction

$$V_{i,I}^{\alpha\beta} = \left|g_{i,I}^{\alpha}\right\rangle \lambda_{i,I}^{\alpha\beta} \left\langle g_{i,I}^{\beta}\right|$$

$$g_I^{\alpha}(k^{\alpha}) = \frac{1}{(k^{\alpha})^2 + (\beta_I^{\alpha})^2}$$

1) Mass M_Λ and width Γ_Λ of the $\Lambda(1405)$ resonance

2) The $K^- p$ scattering length

3) The very accurately measured threshold branching ratio

$$\gamma = \frac{\Gamma(K^- p \to \pi^+ \Sigma^-)}{\Gamma(K^- p \to \pi^- \Sigma^+)} = 2.36 \pm 0.04$$

4) Elastic $K^- p \to K^- p$ and inelastic $K^- p \to \pi^+ \Sigma^-$ total cross sections

NN interaction

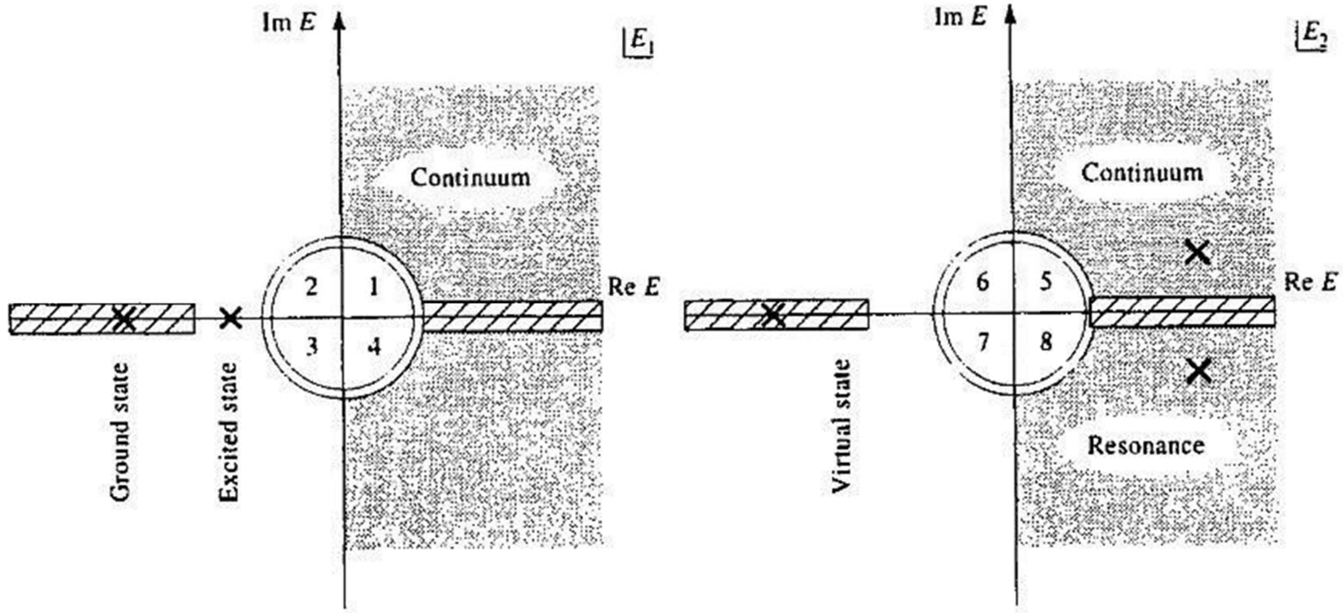
$$g_{I=1}^{NN}(k) = \frac{1}{2\sqrt{\pi}} \sum_{i=1}^{6} \frac{c_{i,I=1}^{NN}}{(k)^2 + \left(\beta_{i,I=1}^{NN}\right)^2}$$

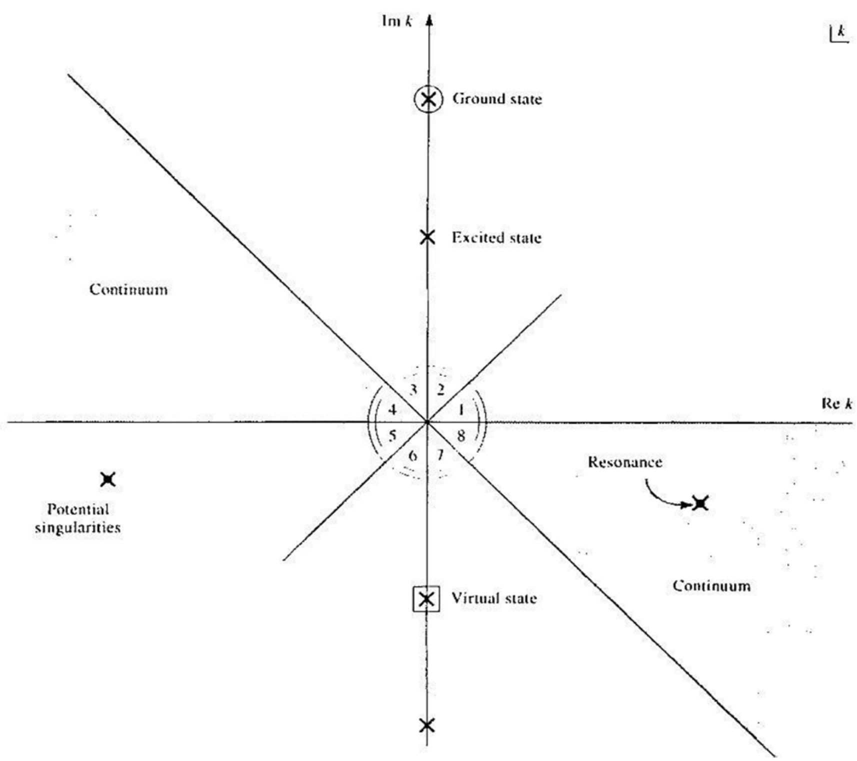
$\bar{K}N$ interaction parameter

$\lambda_{I=0}^{\bar{K}N,\bar{K}N}$	$\lambda_{I=0}^{\bar{K}N,\pi\Sigma}$	$\lambda_{I=0}^{\pi\Sigma,\pi\Sigma}$	$\lambda_{I=1}^{\bar{K}N,\bar{K}N}$	$\lambda_{I=1}^{\bar{K}N,\pi\Sigma}$	$\lambda_{I=1}^{\pi\Sigma,\pi\Sigma}$
0.0062	1.728	-0.342	-1.369	1.412	-0.174

K^-p scattering length (*fm*)	Coupling is of	I=1 interaction is on	I=1 interaction is of
-0.7+0.6i	-45.4	-62.2-57.7i	-60.2-29.7i
-1.0+0.68i	-38.7	-39.0-28.1i	-31.0 -23.5i
-1.07+0.59i	-36.3	-53.6-26.8i	-47.7-24.5i

K^-p scattering length (*fm*)	-0.7+0.6i	-1.0+0.68i	-1.07+0.59i
quasi-bound state energy	-56.6-47.1i	-41.1-35.2i	-34.2-30.7i

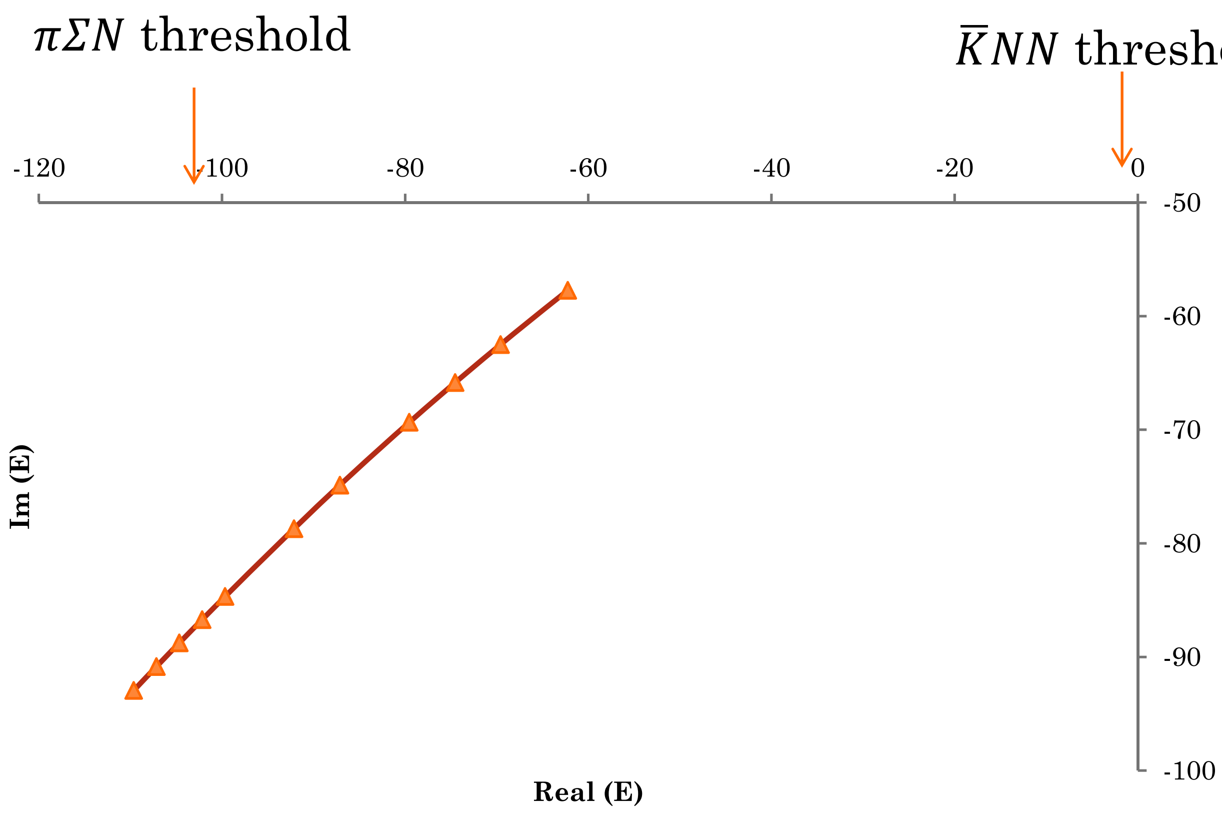

Im E
E1
Continuum
Re E
2
1
3
4
Ground state
Excited state
Im E
E2
Continuum
6
5
7
8
Re E
Virtual state
Resonance


Im k
k
Ground state
Excited state
Continuum
3
2
4
1
Re k
5
8
6
7
Resonance
Potential
singularities
Virtual state
Continuum

Trajectory of the resonance pole

1) Pole state

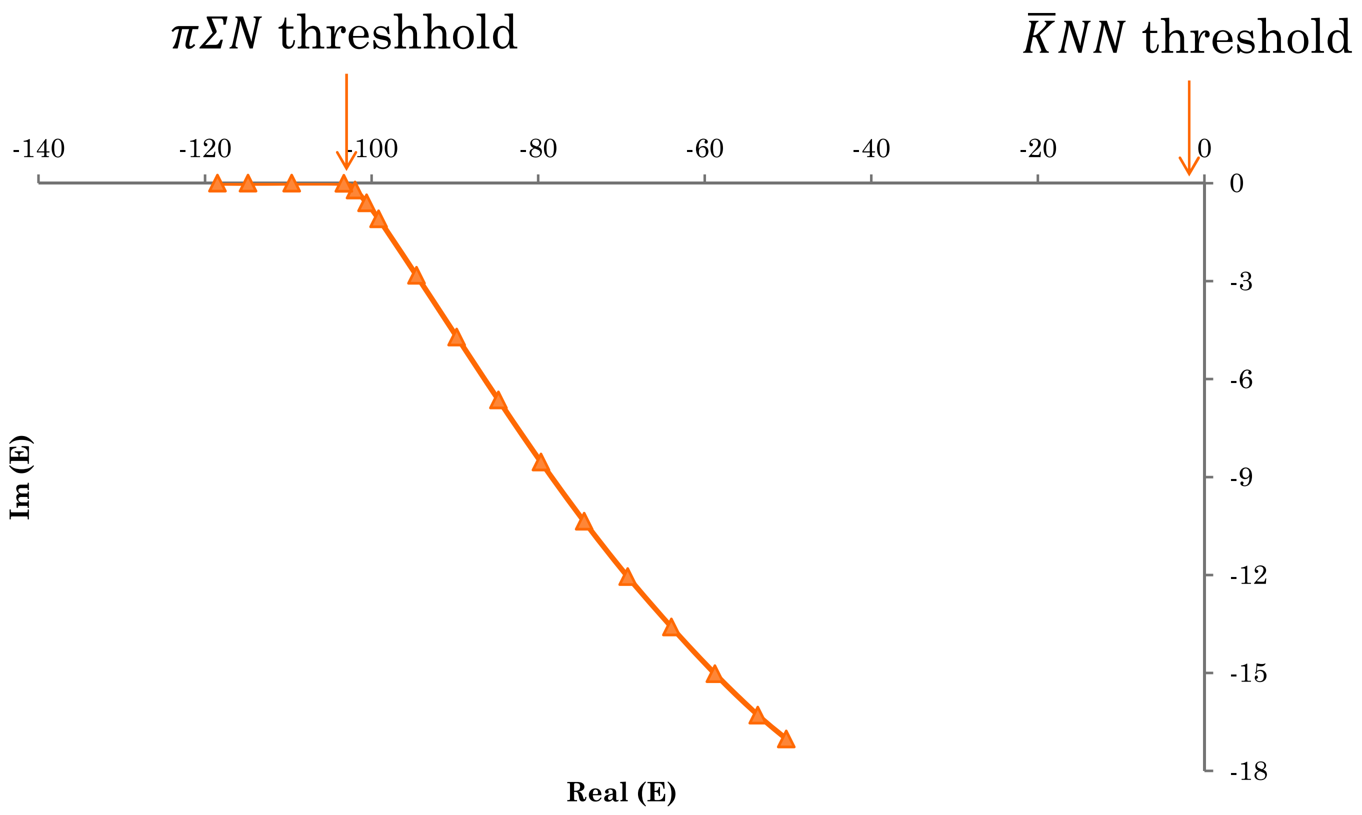
$$\bar{v}^{I=0}_{\bar{K}N,\bar{K}N} = f\, v^{I=0}_{\bar{K}N,\bar{K}N}$$



Trajectory of the resonance pole

Decaying state

$$\bar{v}^{I=0}_{\bar{K}N,\bar{K}N} = f v^{I=0}_{\bar{K}N,\bar{K}N}$$



Summary

The strange dibaryon resonance was studied in $\bar{K}NN - \pi\Sigma N$ system.

We solved the Faddeev equations

--We found the resonance pole of strange dibaryon
on $\bar{K}NN$ physical and $\pi\Sigma N$ unphysical sheet

-- (-B,Γ) = (-40 ~ -65, 50 ~ 110)MeV
for energy-dependent $\bar{K}$N interaction.
-- (-B,Γ) = (-30 ~ -60, 60 ~ 100)MeV
for energy-independent $\bar{K}$N interaction.

The strange dibaryon resonance was studied as pole state and decaying state.

با تشکر