

# Hadronic Resonances in a Hadronic Picture

~ recent topic of hadron structure ~

Daisuke Jido  
(Nuclear physics group)

Hadrons (particles interacting with strong interactions) are composite objects of quarks and gluons.

It has been recently suggested that the structures of some hadrons are understood in hadronic pictures.

Hadronic picture: essential degrees of freedom are hadrons instead of quarks and gluons.

Here we would like to discuss the structures of such hadrons and an interesting conjecture as a result of hadronic picture.

# Hadronic Resonances in a Hadronic Picture

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## Hadrons

- particles interacting with strong interactions
- particles composed by quarks and gluons

**mesons** (bosonic particles) with integer intrinsic spin

**baryons** (fermionic particles) with half-integer spin

*Simple quark picture*      meson: quark and anti-quark  
   baryon: three quarks

**they are the simplest quark contents having color singlet**

ground state hadrons

stable against strong interactions

decay with weak and electromagnetic interactions

excited hadrons = resonances observed in hadronic scatterings

unstable

decay into other hadrons with strong interactions

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Examples of resonances which can be understood in hadronic picture (Exotic hadrons)

## some baryon resonances

described well by meson-baryon quasi bound state

**especially the  $\Lambda(1405)$  baryon resonance**

## light scalar mesons

naive quark model: 1500 MeV

$\sigma(600)$ ,  $f_0(980)$ ,  $\kappa(800)$ ,  $a_0(980)$

meson molecular states and/or multi-quark states ??

## heavy mesons

$X(3872)$ ,  $Y(3940)$ ,  $Y(4260)$  etc.

hard to be understood by quark models

**which work well in spectra of heavy mesons**

meson molecular states, or quark-antiquark state with a gluon

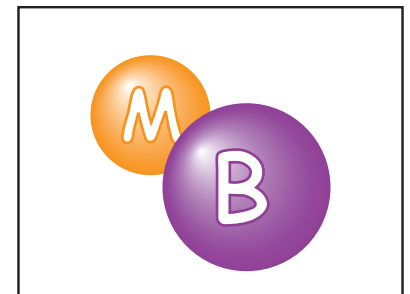
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interesting example of baryon resonances

$\Lambda(1405)$  old candidate of meson-baryon molecular states since 1960's before QCD

considered to be a bound state of K meson and nucleon decaying to pion and Sigma with strong interactions



Quasi bound state  
of meson + baryon

$\bar{K}N$	<u>1435 MeV</u>	$\Lambda(1405)$
		
$\pi\Sigma$	<u>1331 MeV</u>	

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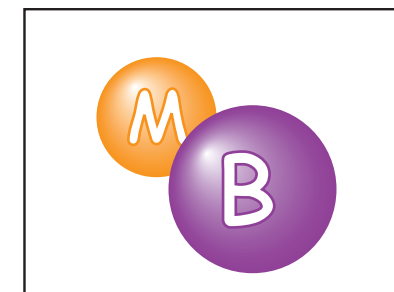
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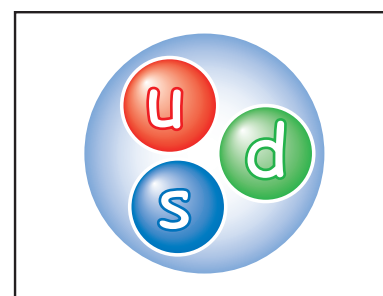
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Quasi bound state of meson + baryon



Three quark state

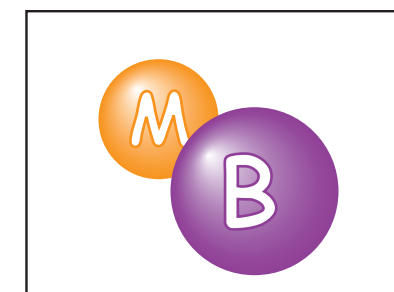
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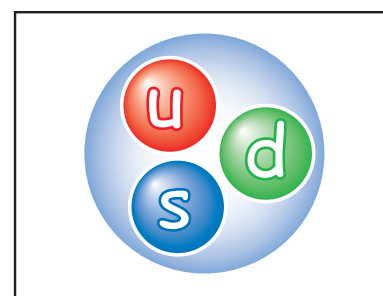
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**recent knowledge of hadron dynamics supports the hadronic picture**

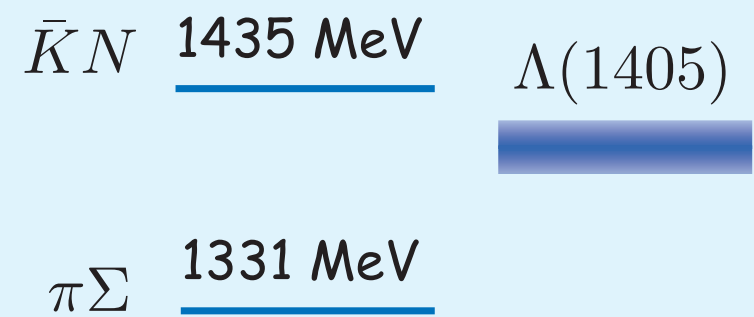
The  $\Lambda(1405)$  is well reproduced by scattering theory with low energy effective theory of QCD, without introducing other than meson-baryon contributions, such as quark contributions.

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$\Lambda(1405)$  is quasi bound state of K meson and nucleon.

Hadronic contributions are essential to understand the structure of  $\Lambda(1405)$ .



The ground state baryons also can be considered to have meson baryon components due to **quantum effects**.

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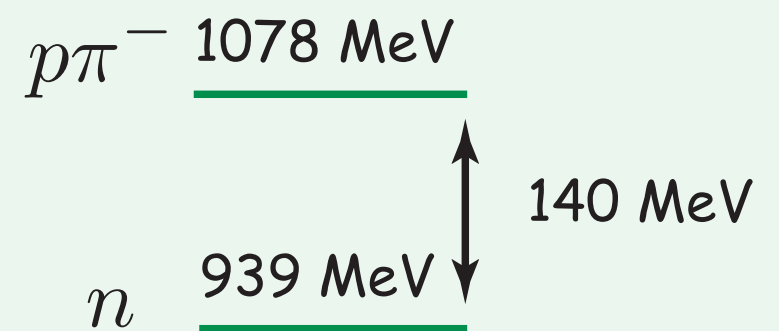


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Ex. neutron

$n \rightarrow p\pi^- \rightarrow n$  pion cloud

explain charge distribution of neutron





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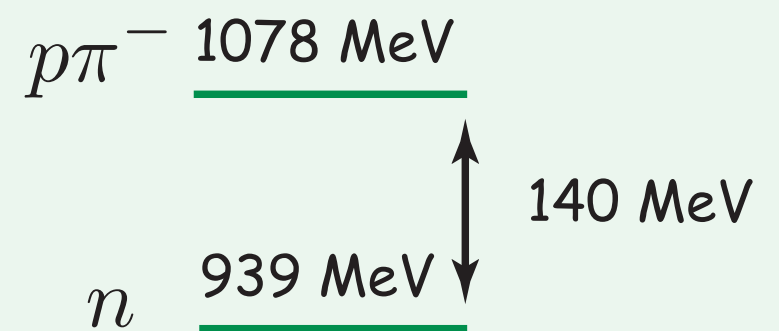


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**pion is virtual !!**

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Interesting conjecture by T.Yamazaki and Y.Akaishi

Let us consider  $ppK^-$  system

Proc. Jpn. Acad., Ser. B 83, 144 (2007)

$\Lambda(1405)$ : quasi bound state of  $pK^-$   
decay to  $\pi\Sigma$

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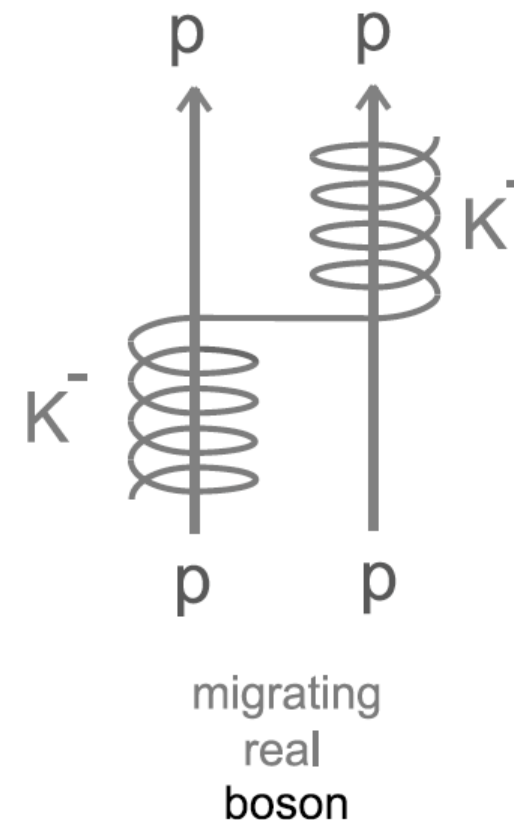
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*Super Strong  
Nuclear Force*  
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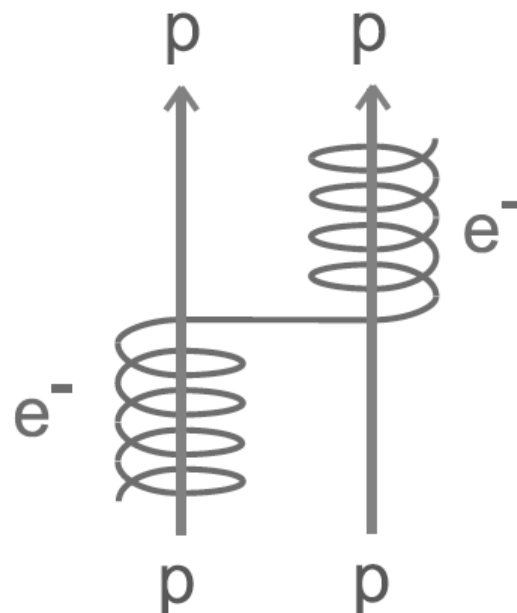
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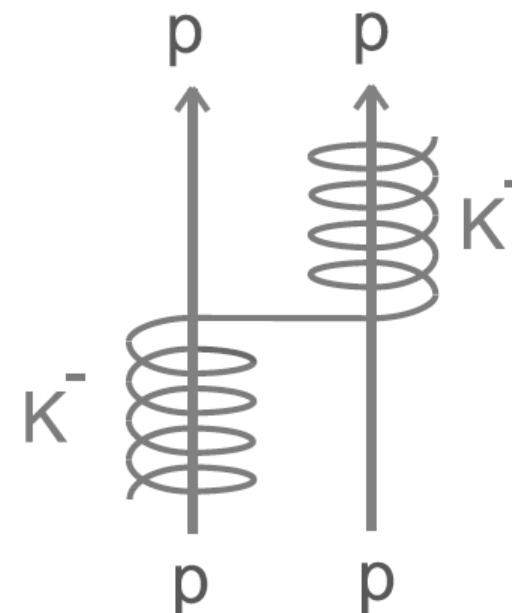
*Molecular*

Heitler-London (1927)  
Heisenberg (1932)

covalent  
bonding  
(共有結合)



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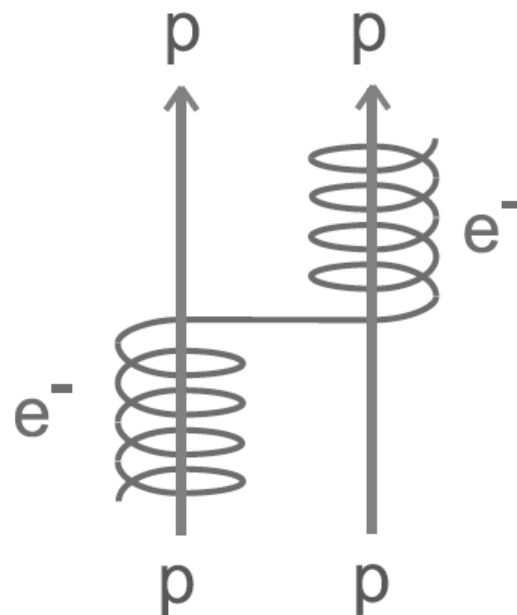
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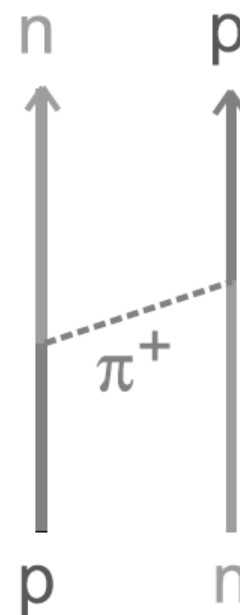
Heitler-London (1927)  
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migrating  
real  
fermion

*Nuclear Force*

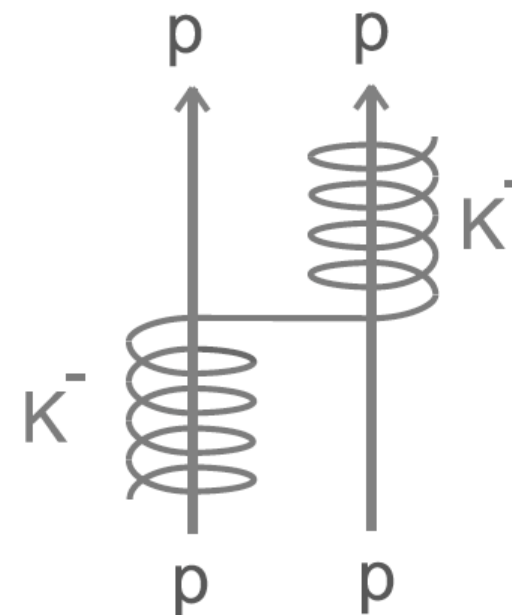
Yukawa (1935)



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If hadronic resonances are bound states of other hadrons, the resonances can create the constituent hadron with much less virtuality.

Consequently, the constituent hadron makes new types of interactions among hadrons. Therefore, such resonances may play important roles especially in hadronic many body systems.

migrating  
real  
fermion

mediating  
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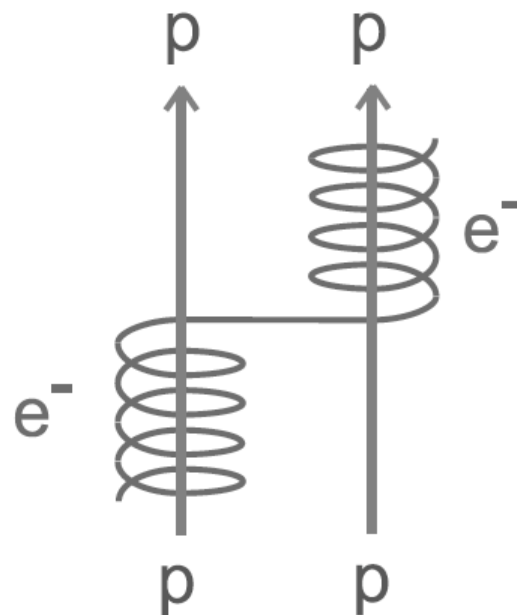
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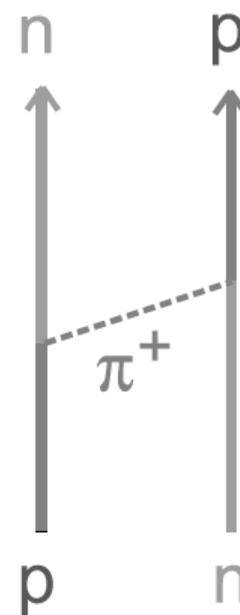
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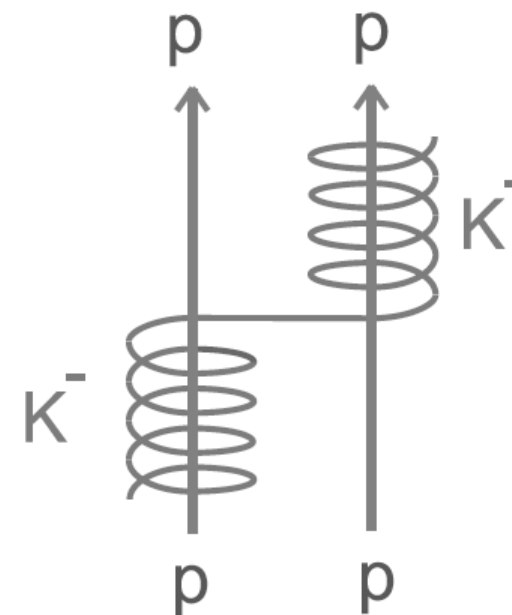
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