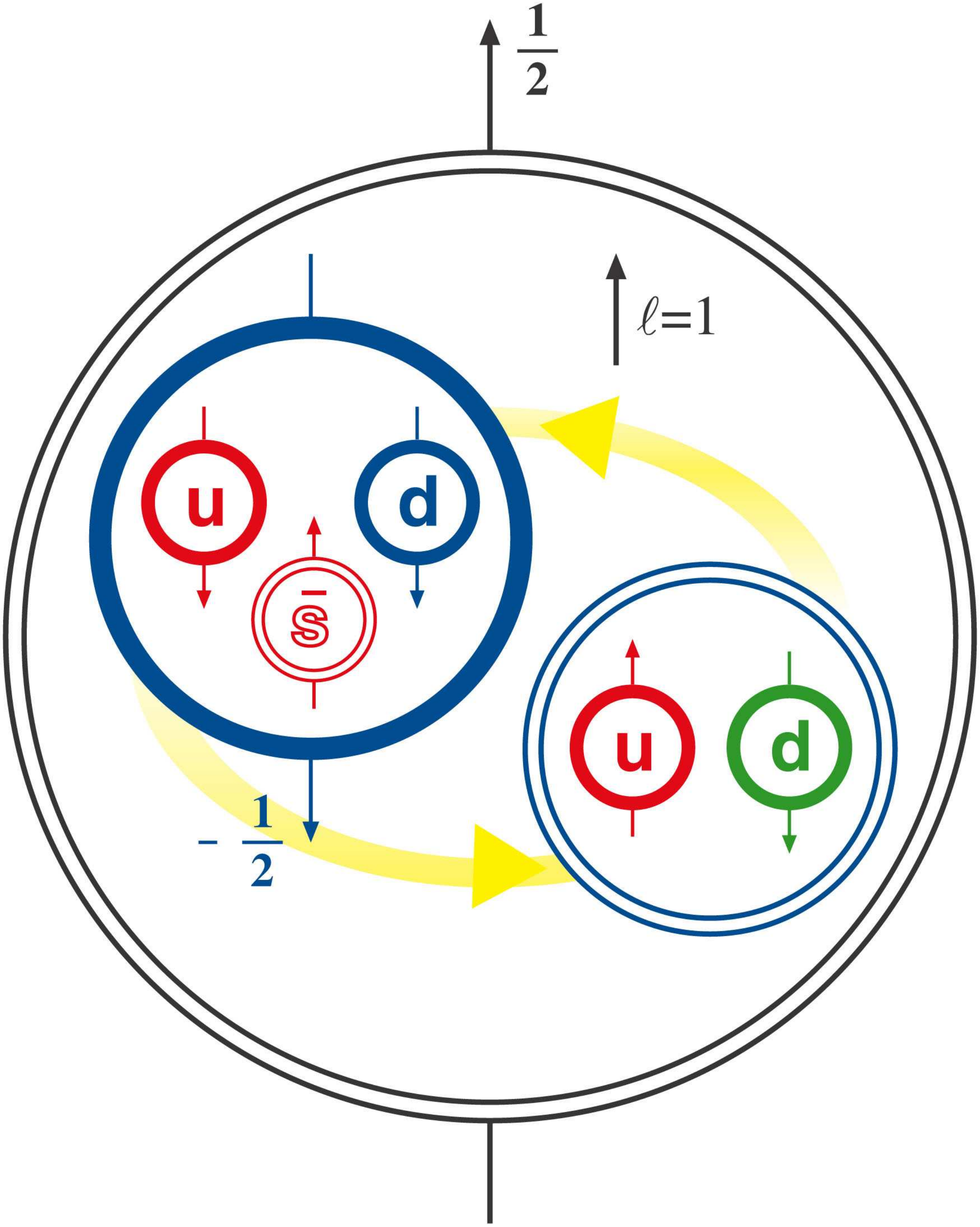

diquark – triquark configuration of the *uudd$\bar{s}$* pentaquark

A Posible Nonstrange Cousin of the Θ^+ pentaquark

Narrow πN resonance (width $\approx$ 25 MeV) at 1680 MeV suggests nonstrange pentaquark

In same SU(3) multiplet as the strange Θ^+ pentaquark with mass 1540 MeV.

We consider extension of diquark-triquark model for Θ^+ to a nonstrange pentaquark

Novel kind of pentaquark with unusual color structure

$\overline{\mathbf{3}}_c$ ud diquark, coupled to $\mathbf{3}_c$ $ud\bar{s}$ triquark in relative P-wave; $J^P = 1/2^+$, $I = 0$

The dynamics of a diquark-triquark pentaquark

Color-magnetic short-range hyperfine interaction V_{hyp} dominant for possible binding.

Color-spin $SU(6)$ algebra simplifies treating configurations absent in normal hadrons.

$V_{hyp} = -V(\vec{\lambda}_i \cdot \vec{\lambda}_j)(\vec{\sigma}_i \cdot \vec{\sigma}_j)$; $\vec{\lambda}$ is $SU(3)_c$ generator and $\vec{\sigma}$ Pauli spin operator

Sign and magnitude normalized by Δ-N mass splitting. Sign shows

qq interaction attractive in states symmetric in color and spin

qq interaction repulsive in antisymmetric states

The "flavor-antisymmetry" principle

Pauli forces two identical fermions to be in repulsive antisymmetric state at short distances

Hyperfine interaction repulsive between uu and dd pairs in nucleon or pentaquark.

Optimum wave function with minimum color-magnetic energy

Keeps like-flavor uu and dd pairs apart, while minimizing the distance and optimizing the color couplings within the other pairs.

Extension of diquark-triquark model for strange pentaquark to nonstrange pentaquark

us diquark instead of the ud diquark in Θ^+ and the same $ud\bar{s}$ triquark

System divided into two color non-singlet clusters separating pairs of identical flavor.

In relative P-wave separated by distance larger than range of color-magnetic force

Clusters kept together by color electric force; hyperfine interaction only within each cluster

us diquark in $\bar{\mathbf{3}}$ of $SU(3)_c$ and $\bar{\mathbf{3}}$ of $SU(3)_f$; $I = 1/2, S = 0$

In symmetric **21** of color-spin $SU(6)$ and antisymmetric in both spin and color.

The $SU(6)$ **21** contains color $\bar{\mathbf{3}}$ with spin 0 and a color **6** with spin 1.

ud in $ud\bar{s}$ triquark in **6** of $SU(3)_c$, in $\bar{\mathbf{3}}$ of $SU(3)_f$; $I = 0, S = 1$.

In symmetric **21** of color-spin $SU(6)$ and symmetric in both spin and color.

Triquark has diquark and antiquark coupled to $SU(3)_c$ triplet and has $I = 0, S = 1/2$.

In fundamental **6** representation of the color-spin $SU(6)$ and in a $\bar{\mathbf{6}}$ of $SU(3)_f$.

Two possible U(3) flavor couplings for us diquark in $\bar{\mathbf{3}}$ and triquark in $\bar{\mathbf{6}}$ of $SU(3)_f$.

$6 \times 3 = 18 = 10 + 8$

General pentaquark has two allowed $SU(3)_f$ couplings $\bar{\mathbf{10}}$ and **8** of $SU(3)_f$.

Only $\bar{\mathbf{10}}$ antidecuplet allowed for Θ^+; no positive strangeneess state in octet.

Nonstrange pentaquarks mix octet and antidecuplet like singlet-octet ($\omega - \phi$ mixing.

Mixing determined by dominant symmetry-breaking; $m_s - m_d$

Diquark-triquark model mixes nonstrange octet and antidecuplet states,

Either both diquark and triquark are nonstrange or two have opposite strangeness.

We choose us diquark and same strange triquark used for the Θ^+ .

Conventional notation $|D_6, D_3, S, N\rangle$

Diquarks with spin S, denoted by $\left|(2q)^S\right\rangle$ and triquark, $\left|(2q\bar{s})^{\frac{1}{2}}\right\rangle$,

D_6 and D_3 denote dimensions of color-spin $SU(6)$ and color $SU(3)$ representations

S and N denote the total spin and the number of quarks in the system,

$\left|\ (2q)^1\ \right\rangle|21, 6, 1, 2\rangle\,; \quad \left|\ (2q)^0\ \right\rangle|21, \bar{3}, 0, 2\rangle\,; \quad \left|(2q\bar{s})^{\frac{1}{2}}\right\rangle - \left|\ 6, 3, \tfrac{1}{2}, 3\right\rangle$

Standard treatment using the $SU(6)$ color-spin algebra shows

Hyperfine interaction stronger for diquark-triquark system than KN system

In $SU(3)_f$ symmetry limit

$[V(2q\bar{s}^{\frac{1}{2}}) + V(2q^0)] - [V(K) + V(N)] = -\frac{1}{6}(M_\Delta - M_N) \approx -50\text{MeV}$

The physics here is simple.

Spin-zero diquark same as diquark in Λ with same hyperfine energy as nucleon.

Triquark with one quark coupled with $\bar{s}$ antiquark to spin zero has same hyperfine energy as a kaon but no interaction with the other quark.

The triquark coupling allows $\bar{s}$ antiquark to interact with both u and d quarks and gain hyperfine energy with respect to the case of the kaon.

Isolated triquark is not color singlet, but triquark color charge neutralized by the diquark.

We now note that in the SU(3) symmetry limit we can rewrite

$[V(2q\bar{s}^{\frac{1}{2}}) + V(2q^0)] - [V(K) + V(\Lambda)] = -\frac{1}{6}(M_\Delta - M_N) \approx -50\text{MeV}$

With first order symmetry breaking $M(\Lambda) \neq M(N)$ and

The mass of πN pentaquark is predicted to be higher than Θ^+ mass by $M(\Lambda) - M(N)$

$M(\pi N)_{pred} = M(\Theta^+) + M(\Lambda) - M(N) = 1540 + 180 = 1720; \quad M(\pi N)_{exp} = 1680$

Not bad for such a crude calculation

The $uudd\bar{s}$ pentaquark really complicated five-body system

Flavor antisymmetry suggests that the commonly used bag or single-cluster models

May be correct to treat normal hadrons not adequate for multiquark systems.

These models have identical pair correlations for all pairs in the system,

They miss the flavor anisymmetry which requires different pair correlations for pairs with the same flavor and for pairs with different flavors.