Five-quark components in the proton and the lowest ½- baryon resonances

Bing-Song Zou

Institute of High Energy Physics, CAS, Beijing

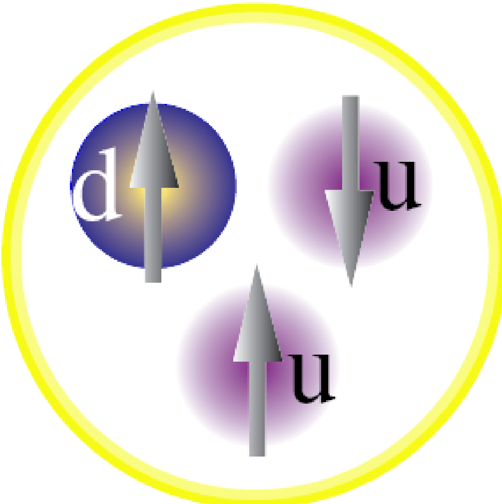
Outline：

- 5-quark components in the proton
- New scheme for N*(1535) and its1/2$^-$ nonet partners
- New scheme for Δ*(1620) and its1/2$^-$ 10-plet partners
- Conclusion

1. 5-quark components in the proton

Classical picture of the proton

Constituent Quarks



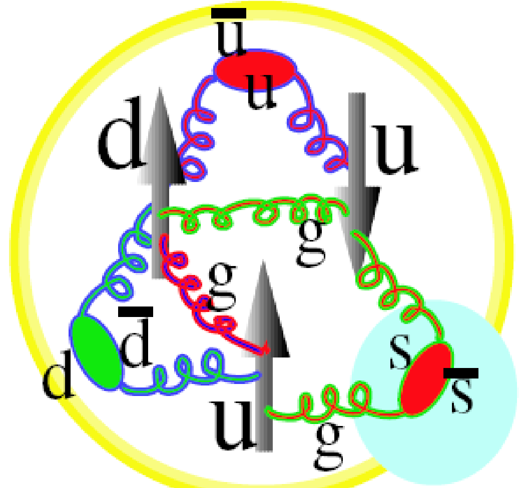
($Q^2 = 0$ GeV^2)

baryon octet

masses,magn. momenta

1964-1974

Parton Distributions



($Q^2 > 1$ GeV^2)

structure functions

momentum, spin

$$\bar{u}(x) = \bar{d}(x)\ , \quad \bar{s}(x) = s(x)$$

1974–1992

Flavor asymmetry of light quarks in the nucleon sea

Deep Inelastic Scattering (DIS) + Drell-Yan (DY) process

→ $\bar{d} - \bar{u} \sim 0.12$

Garvey&Peng, Prog. Part. Nucl. Phys.47, 203 (2001)

Table 1. Values of the integral $\int_0^1 [\bar{d}(x) - \bar{u}(x)]dx$ determined from the DIS, semi-inclusive DIS, and Drell-Yan experiments.

Experiment	$\langle Q^2 \rangle$ (GeV^2/c^2)	$\int_0^1 [\bar{d}(x) - \bar{u}(x)]dx$
NMC/DIS	4.0	0.147 ± 0.039
HERMES/SIDIS	2.3	0.16 ± 0.03
FNAL E866/DY	54.0	0.118 ± 0.012

Two major theoretical schemes for $\bar{d} - \bar{u} \sim 0.12$

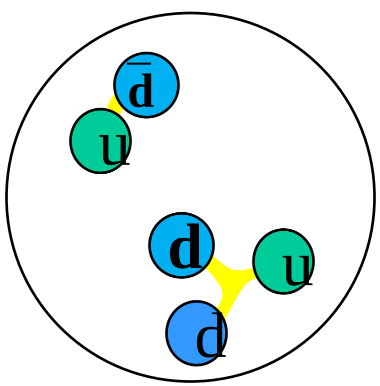
Meson cloud picture: Thomas, Speth, Weise, Oset, Brodsky, Ma, …

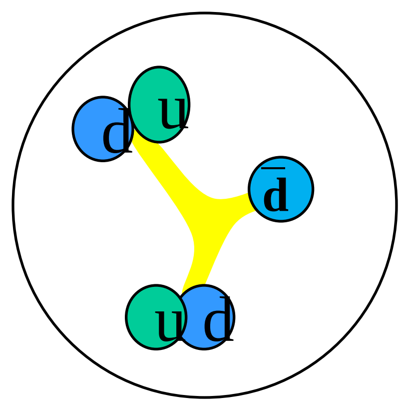
$$| p > \sim | uud > + \varepsilon_1 | n (udd) \pi^+ (\bar{d}u) >$$

$$+ \varepsilon_2 | \Delta^{++} (uuu) \pi^- (\bar{u}d) > + \varepsilon' | \Lambda (uds) K^+ (\bar{s}u) > \ldots$$

Penta-quark picture : Riska, Zou, Zhu, …

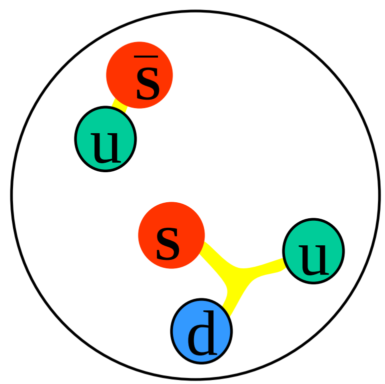
$$| p > \sim | uud > + \varepsilon_1 | [ud][ud] \bar{d} > + \varepsilon' | [ud][us] \bar{s} > + \ldots$$

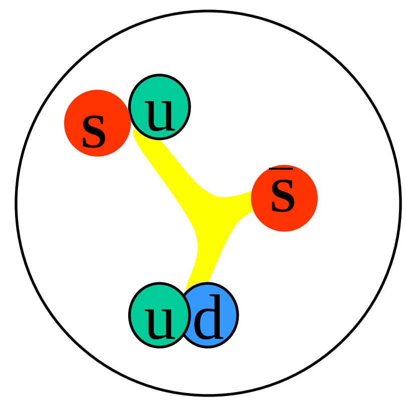




Predictions for $\bar{s}$ / s asymmetry from two schemes :

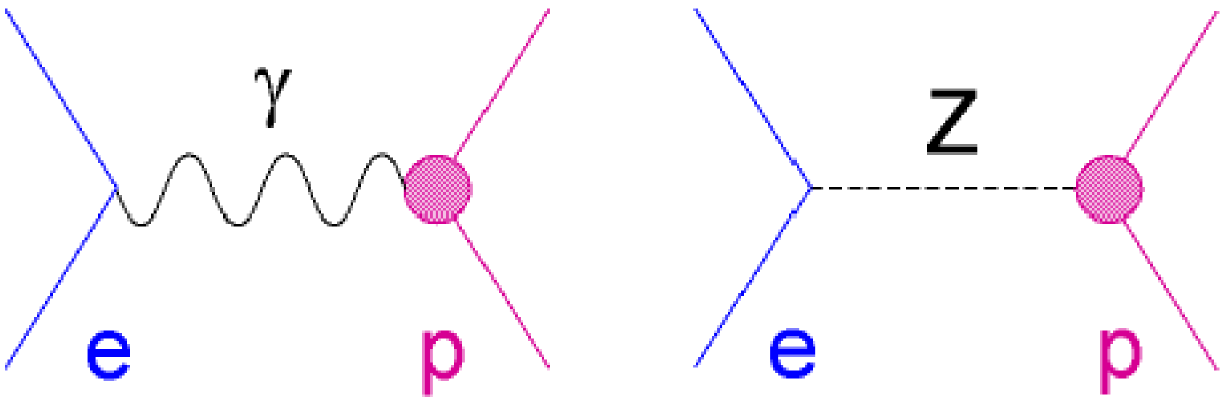
	meson cloud	penta-quark
strange spin Δs :	< 0	< 0
magnetic moment μ_s :	< 0	> 0
strange radium r_s :	< 0	> 0





Expt: $\Delta s = -0.05 \sim -0.1$ D. de Florian et al., PRD71 (2005) 094018

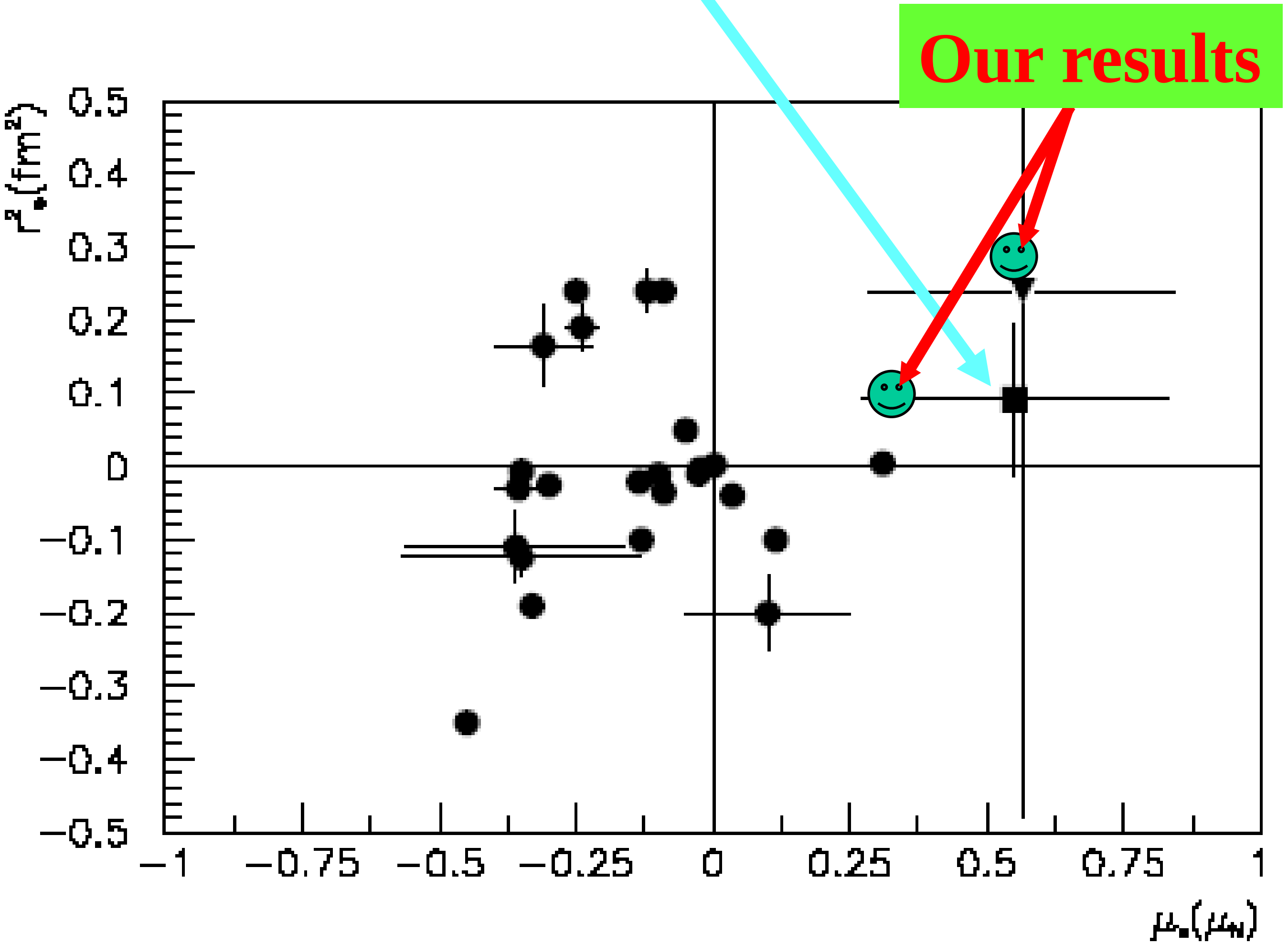
The strange magnetic moment μ_s and radii r_s from parity violating electron scattering



G0,HAPPEX/CEBAF, SAMPLE/MIT-Bates, A4/MAMI

HAPPEX/CEBAF, Phys.Rev.Lett. 96 (2006) 022003
G0/CEBAF, Phys.Rev.Lett. 95 (2005) 092001
A4/MAMI, Phys.Rev.Lett. 94 (2005) 152001
SAMPLE/MIT-Bates: Phys.Lett.B583 (2004) 79

Theory vs experiment for μ_s and r_s



Zou&Riska, PRL95(2005)072001; Riska&Zou, PLB636 (2006) 265
An-Riska-Zou, PRC73 (2006) 035207

Experiment extraction of μ_s and r_s wrong?

R.Young et al., PRL97 (2006) 102002 → $\mu_s \sim 0$

With ~25% $\bar{q}qqqq$ components in the proton, the "spin crisis" and single spin asymmetry may also be naturally explained.

An-Riska-Zou, PRC73 (2006) 035207; F.X.Wei, B.S.Zou, hep-ph/0807.2324

We must go beyond the simple 3q models,

meson cloud vs penta-quark not settled yet.

2. New scheme for N*(1535) and its $1/2^-$ nonet partners

- **Mass order reverse problem for the lowest excited baryons**

  uud (L=1) ½ - ~ N*(1535) should be the lowest

  uud (n=1) ½ + ~ N*(1440)

  uds (L=1) ½ - ~ Λ*(1405)

  harmonic oscillator (2n + L + 3/2) ħω

- **Strange decays of N*(1535)**

$J/\psi \rightarrow \bar{p}N^* \rightarrow \bar{p}\,(K\Lambda)\,/\,\bar{p}\,(p\eta) \rightarrow g_{N^*K\Lambda}/g_{N^*p\eta}/g_{N^*p\pi} \sim 2:2:1$

B.C. Liu, B.S. Zou, PRL96 (2006) 042002; PRL98 (2007) 039102

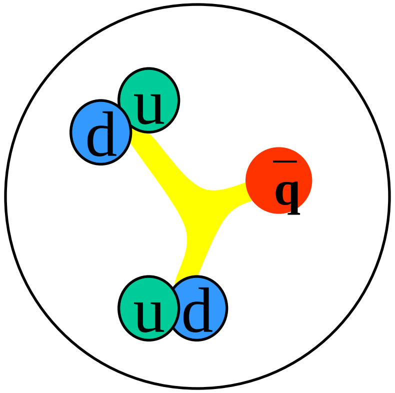
$\gamma p \rightarrow p\eta'$ & $pp \rightarrow pp\eta' \rightarrow$ large $g_{N^*N\eta'}$

M.Dugger et al., PRL96 (2006) 062001; X.Cao, X.G.Lee, PRC(2008)

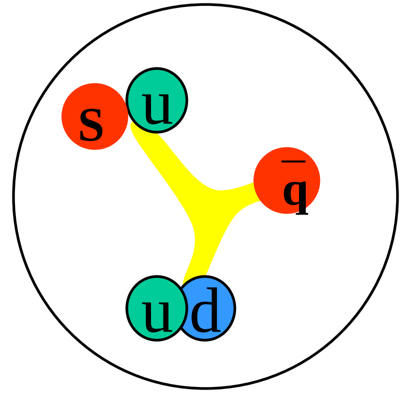
$\pi^- p \rightarrow n\phi$ & $pp \rightarrow pp\phi \rightarrow$ large $g_{N^*N\phi}$

Xie, Zou & Chiang, PRC77(2008)015206

New Scheme for N*(1535) and its 1/2⁻ nonet partners



$\bar{q}$ ½+
[ud]
[ud] } L=1



$\bar{q}$ ½ -
[ud]
[us] } L=0

Zhang et al, hep-ph/0403210

N*(1535) ~ uud (L=1) + ε [ud][us] $\bar{s}$ + …

N*(1440) ~ uud (n=1) + ξ [ud][ud] $\bar{d}$ + …

Λ*(1405) ~ uds (L=1) + ε [ud][su] $\bar{u}$ + …

N*(1535): [ud][us] $\bar{s}$ → larger coupling to Nη, Nη', Nϕ & KΛ, weaker to Nπ & KΣ, and heavier !

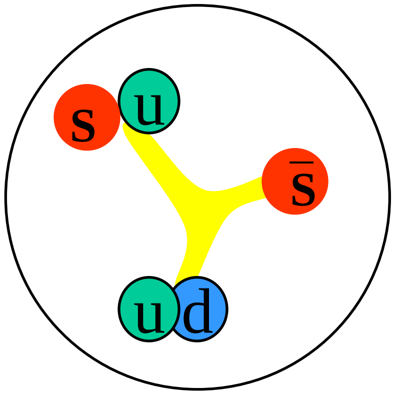
The new scheme for the $1/2^-$ nonet predicts:

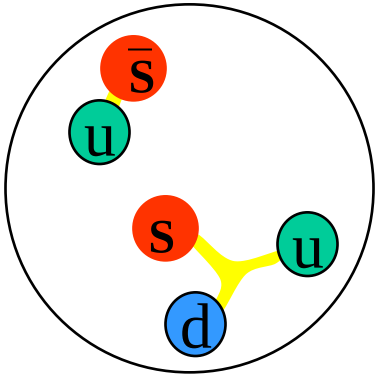
Λ^*	$[us][ds]\,\bar{s}$	~	1575 MeV
Σ^*	$[us][du]\,\bar{d}$	~	1360 MeV
Ξ^*	$[us][ds]\,\bar{u}$	~	1520 MeV

J/ψ decay		branching ratio * 10^4	
$\bar{p}\,\Delta(1232)^+$	3/2+	< 1	SU(3) breaking
$\bar{\Sigma}^-\,\Sigma(1385)^+$		3.1 ± 0.5	
$\bar{\Xi}^+\,\Xi(1530)^-$		5.9 ± 1.5	
$\bar{p}\,N^*(1535)^+$	1/2-	10 ± 3	SU(3) allowed
$\bar{\Sigma}^-\,\Sigma(1360)^+$		?	
$\bar{\Xi}^+\,\Xi(1520)^-$		?	

It is very important to check whether under the Σ(1385) and Ξ(1520) peaks there are $1/2^-$ components ?

Weise, Oset et al: N*(1535) as K Λ-KΣ state, Λ*(1405) as KN state





Pentaquark vs Meson Cloud

More solid information on its $1/2^-$ nonet partners are needed !

3. New scheme for Δ*(1620) and its1/2⁻ 10-plet partners

Δ^{++*} (1620) ½ ⁻ -- The lowest excited uuu state with L=1 in classical 3q models

$\pi^+ p \rightarrow \rho^+ p$ & $pp \rightarrow nK^+\Sigma^+ \rightarrow$ very large $g_{\Delta^* N\rho}$

J.J.Xie, B.S.Zou, PLB649 (2007) 405

→	**Δ*(1620) ½-**	**ρN molecule ?**	**1705 MeV**
	Σ*(1750) ½-	**K*N molecule ?**	**1820 MeV**
	Ξ*(1950) ½-?	**K*Λ molecule ?**	**2010 MeV**
	Ω*(2160) ½-?	**K*Ξ molecule ?**	**2215 MeV**

1/2⁻ baryon decuplet ~ V_8B_8 molecules ?

see also talk by Oset .

Conclusion

- **Meson-cloud vs diquark cluster for $\bar{d} - \bar{u} \sim 0.12$**
- **Predictions for the strangeness in the proton:**

meson cloud : $\Delta s < 0$, $\mu_s < 0$, $r_s < 0$

diquark cluster : $\Delta s < 0$, $\mu_s > 0$, $r_s > 0$

- **$\bar{q}qqqq$ in S-state more favorable than qqq with L=1 !**

$1/2^-$ baryon nonet ~ $\bar{q}q^2q^2$ state + …

$1/2^-$ baryon decuplet ~ V_8B_8 molecules + …

5-quark components are important for all baryons!