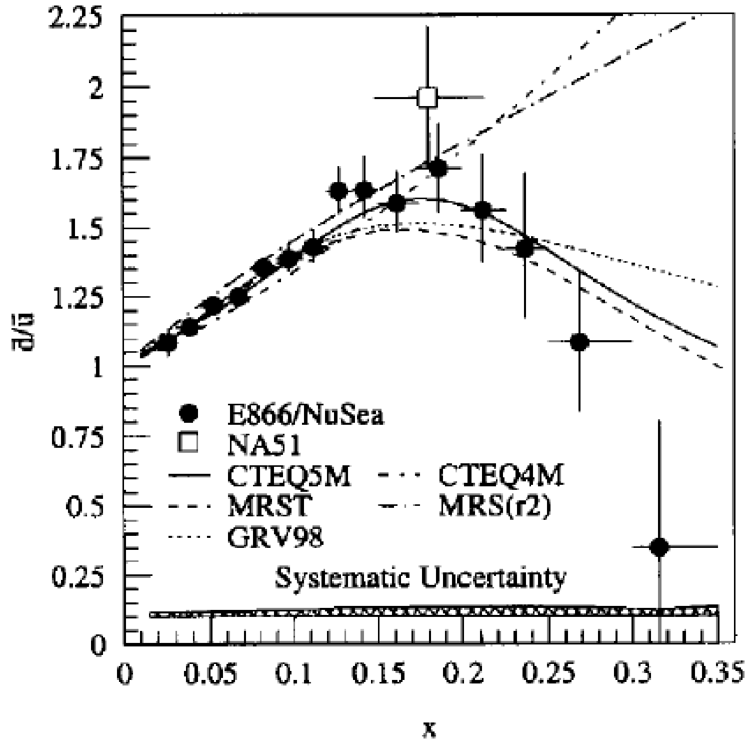
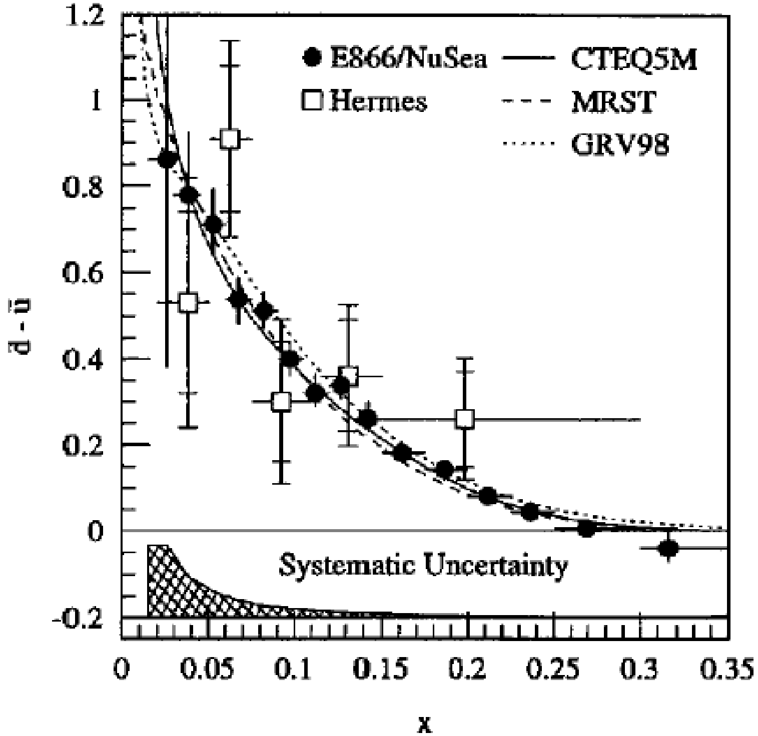
FLAVOR ASYMMETRY IN THE PROTON

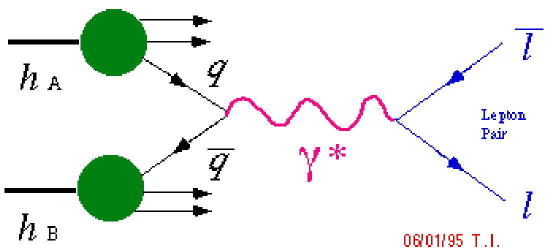
$uud(u\bar{u}) \quad uud(d\bar{d})$





G.Garvey and J.C.Peng, Prog.Part.Nucl.Phys. 47, 203 (2001)

The Drell-Yan Process

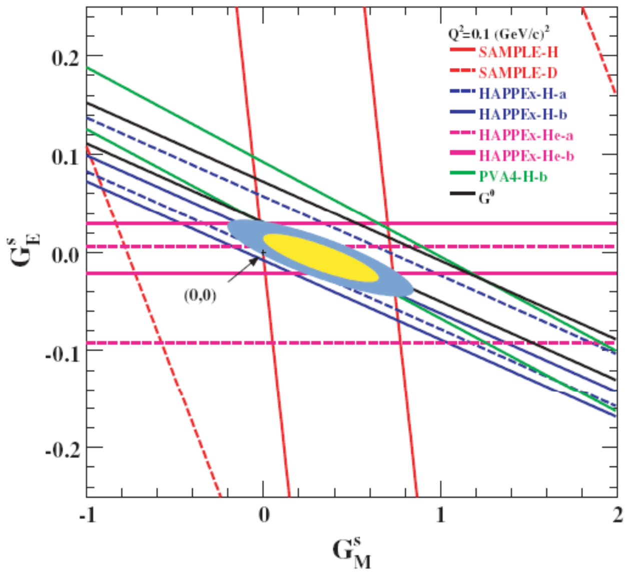


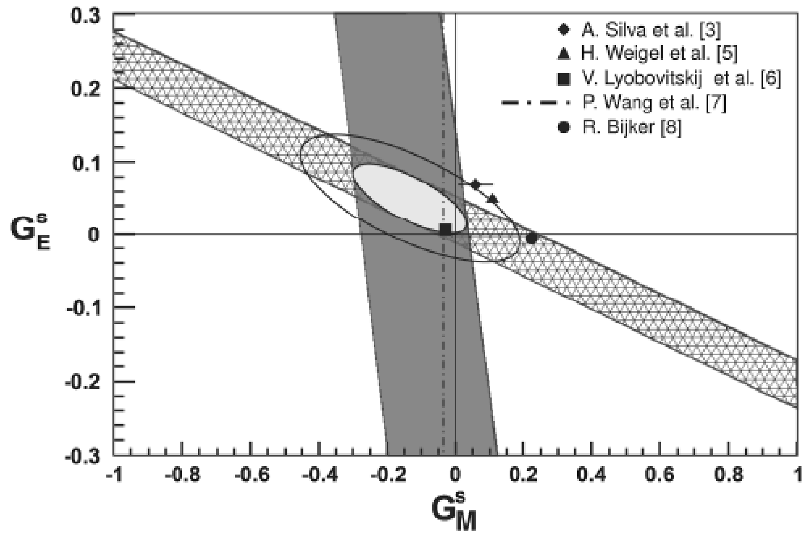
$$\bar{d}/\bar{u} > 1$$

THE STRANGENESS FORM FACTORS OF THE PROTON

PHYSICAL REVIEW C **76**, 025202 (2007)

$uuds\bar{s}$





$$G^s_M = 0.29 \pm 0.21$$

$$G^s_E = -0.008 \pm 0.016$$

low Q^2: 0.077 ... 0.23 $(\mathrm{GeV}/c)^2$

J. Liu et al, PRC76, 025202 (2007)

$$G^s_M = -0.14 \pm 0.11 \pm 0.11$$

$$G^s_E = 0.050 \pm 0.038 \pm 0.019$$

$$Q^2 = 0.22\ (\mathrm{GeV}/c)^2$$

S. Baunack et al. (A4), PRL 102, 151803 (2009)

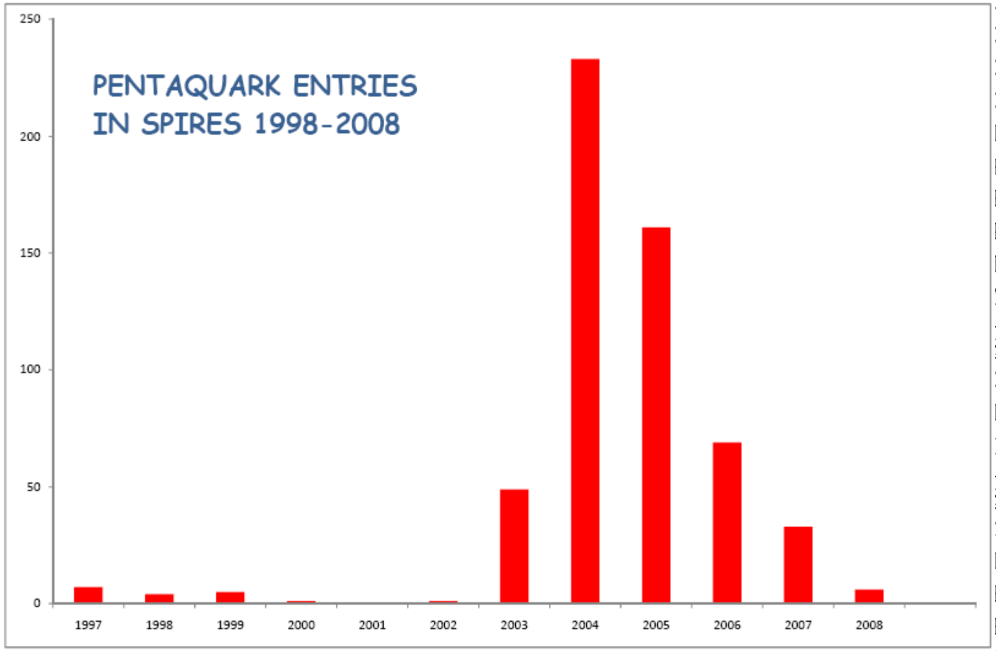
Backward G0 preliminary : $G_E{}^s$ and $G_M{}^s$ very small

strange pentaquarks ?

C. Amsler *et al.* (Particle Data Group), PL **B667**, 1 (2008) (URL: http://pdg.lbl.gov)

Table 1: Unsuccessful searches for pentaquarks. There are ten more unsuccessful searches for the $\Theta(1540)$, nine for the $\Phi(1860)$, and three for the $\Theta_c(3100)$ listed in our 2006 edition [1].

Experiment	Reaction	Energy, etc.	Limits, etc.
Searches for the $\Theta(1540)^+$			
BABAR [2]	$B^0 \to (pK^0_S)\bar{p}$	$\sqrt{s}$ 10.58 GeV	$< 2 \times 10^{-7}$ per B^0
CLAS [3]	$\gamma p \to (nK^+/pK^0_S)K^0$	E_γ 1.6–3.8 GeV	$\sigma < 0.7$ nb, 100k $\Lambda(1520)$
CLAS [4]	$\gamma d \to (nK^+)pK^-$	E_γ 0.8–3.6 GeV	$\sigma < 0.3$ nb
CLAS [5]	$\gamma d \to (nK^+)\Lambda$	E_γ 0.8–3.6 GeV	$\sigma < 5$–25 nb
COSY-ANKE [6]	$pp \to (pK^0_S)\Lambda\pi^+$	p_p 3.65 GeV/c	$\sigma < 58$ nb
COSY-TOF [7]	$pp \to (pK^0_S)\Sigma^+$	p_p 3.059 GeV/c	$\sigma < 150$ nb
DELPHI [8]	$Z \to (pK^0_S)X$	$\sqrt{s}$ 91.2 GeV	$< 5.1 \times 10^{-4}$ per Z
FOCUS [9]	$\gamma A \to (pK^0_S)X$	$\bar{E}_\gamma$ 180 GeV	400k $\Sigma(1385)^+$
HERA-H1 [10]	$ep \to (p/\bar{p}K^0_S)eX$	$5 < Q^2 < 100$ GeV^2	$\sigma < 30$–90 pb
KEK-E522 [11]	$\pi^- p \to K^-(X)$	p_π 1.9 GeV/c	$\sigma < 3.9$ nb
L3 [12]	$\gamma^*\gamma^* \to (p/\bar{p}K^0_S)X$	$E_{\gamma\gamma} > 5$ GeV	$\sigma < 1.8$ nb
NOMAD [13]	$\nu_\mu N \to (pK^0_S)X$		< 2.13x10^{-3} per evt
Searches for a pK^+ state			
CLAS [14]	$\gamma p \to (pK^+)K^-$	E_γ 1.8–3.8 GeV	$\sigma < 0.15$ nb
DELPHI [8]	$Z \to (pK^+)X$	$\sqrt{s}$ 91.2 GeV	$< 1.6 \times 10^{-3}$ per Z
JLAB-HALL-A [15]	$ep \to eK^-(X)$	E_e 5 GeV	$< 5\%$ of $\Lambda(1520)$
Searches for the $\Phi(1860)$			
CDF [16]	$\bar{p}p \to (\Xi^-\pi^\pm)X$	$\sqrt{s}$ 1.96 TeV	1.9k $\Xi(1530)^0$
DELPHI [8]	$Z \to (\Xi^-\pi^-)X$	$\sqrt{s}$ 91.2 GeV	$< 2.9 \times 10^{-4}$ per Z
FOCUS [17]	$\gamma N \to (\Xi^-\pi^-)X$	$\bar{E}_\gamma$ 180 GeV	65k $\Xi(1530)^0$
HERA-H1 [18]	$ep \to (\Xi^-\pi^\pm)eX$	$2 < Q^2 < 100$ GeV^2	163 $\Xi(1530)^0$
SERP-EXCHARM [19]	$nC \to (\Xi^-\pi^\pm)X$	$\bar{E}_n$ 51 GeV	1.5k $\Xi(1530)^0$
Searches for the $\Theta_c(3100)$			
BABAR [20]	$e^+e^- \to (pD^{*-})X$	$\sqrt{s}$ 10.58 GeV	125k evts
CHORUS [21]	$\bar{\nu}_\mu A \to \mu^+ X$	$\bar{E}_\nu$ 18 GeV	2262 evts
DELPHI [8]	$Z \to (pD^{*-})X$	$\sqrt{s}$ 91.2 GeV	$< 8.8 \times 10^{-4}$ per Z



Maybe evenso ?

PHYSICAL REVIEW C **79**, 025210 (2009)

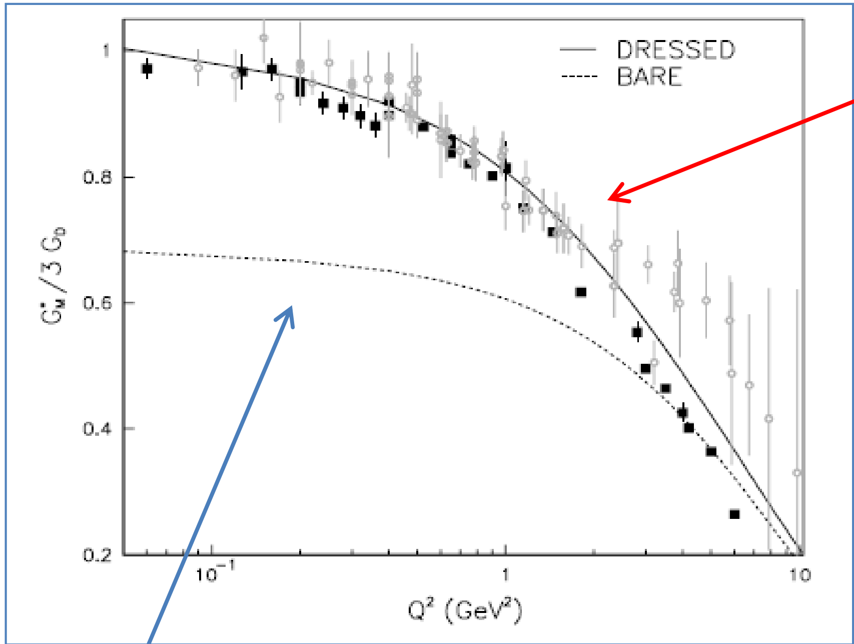
Evidence for the Θ^+ in the $\gamma d \to K^+K^- pn$ reaction by detecting K^+K^- pairs

THE "MESON" CLOUD

NΔ magnetic form factor:
hadronic coupled channels model

B. Juliá-Díaz,[1,2] T.-S. H. Lee,[1,3] T. Sato,[1,4] and L. C. Smith[1,5]

PHYSICAL REVIEW C 75, 015205 (2007)



Deviation due to meson cloud !

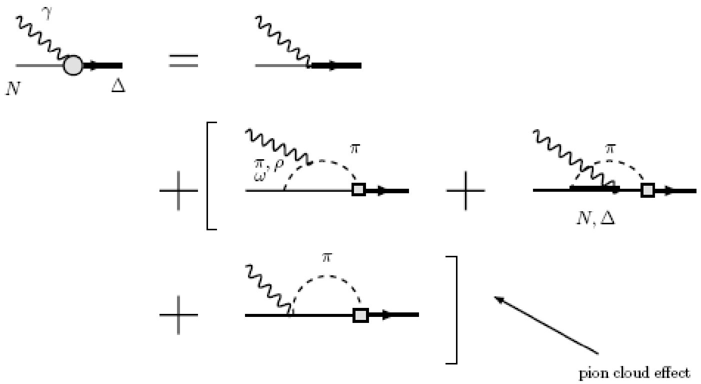


FIG. 2. Graphic representation of the dressed $\gamma N \to \Delta$ vertex defined by Eqs. (2.8)–(2.10).

~ quark model result

		IA	Exp
$\Delta^+ \to p$	$\frac{2\sqrt{2}}{3}\frac{m_N}{m_u^*}$	3.1	2.6

COVARIANT QUARK MODEL FOR DIFFERENT KINEMATICS

TABLE II. Axial form factors at the pion point $|G_A(-m_\pi^2)|$. The PHEN column contains the corresponding axial coupling constants that have been obtained phenomenologically from the imaginary parts of the corresponding resonance pole positions [15] using Eqs. (22) and (24).

	Instant	Point	Front	PHEN
$\Delta(1232)$	1.74	1.70	1.79	2.67
$N(1440)$	0.11	0.07	0.10	[0.38–0.41]
$N(1535)$	0.24	0.20	0.31	[0.20–0.25]
$\Delta(1600)$	0.30	0.06	0.38	[0.48–0.75]

B. Juliá-Díaz* and D. O. Riska†

F. Coester‡

PHYSICAL REVIEW C **70**, 045204 (2004)

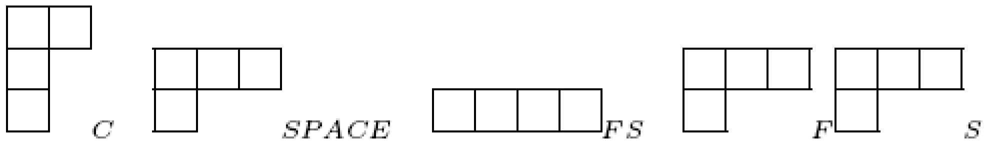
TABLE III. Pion decay widths in MeV that correspond to two times the imaginary pole positions in [15].

	Instant	Point	Front	PHEN [15]
$\Delta(1232)$	42	41	45	100
$N(1440)$	10	4	8	[126–147]
$N(1535)$	84	60	147	[59–93]
$\Delta(1600)$	12	0	19	[30–75]

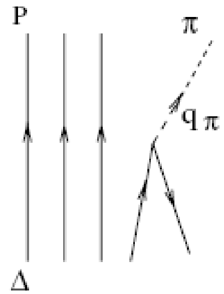
N(1440) poorly described as a qqq state

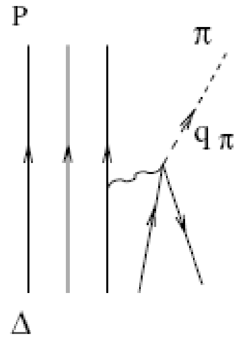
$qqqq\bar{q}$ enhancement of quark model result for Δ decay

simplest $qqqq\bar{q}$ configuration: $[4]_{FS}[31]_F[31]_S$



main contribution from
cross term matrix elements

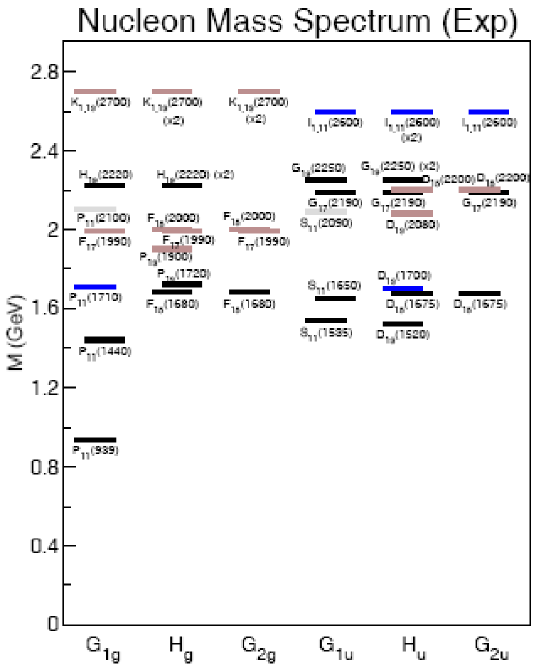




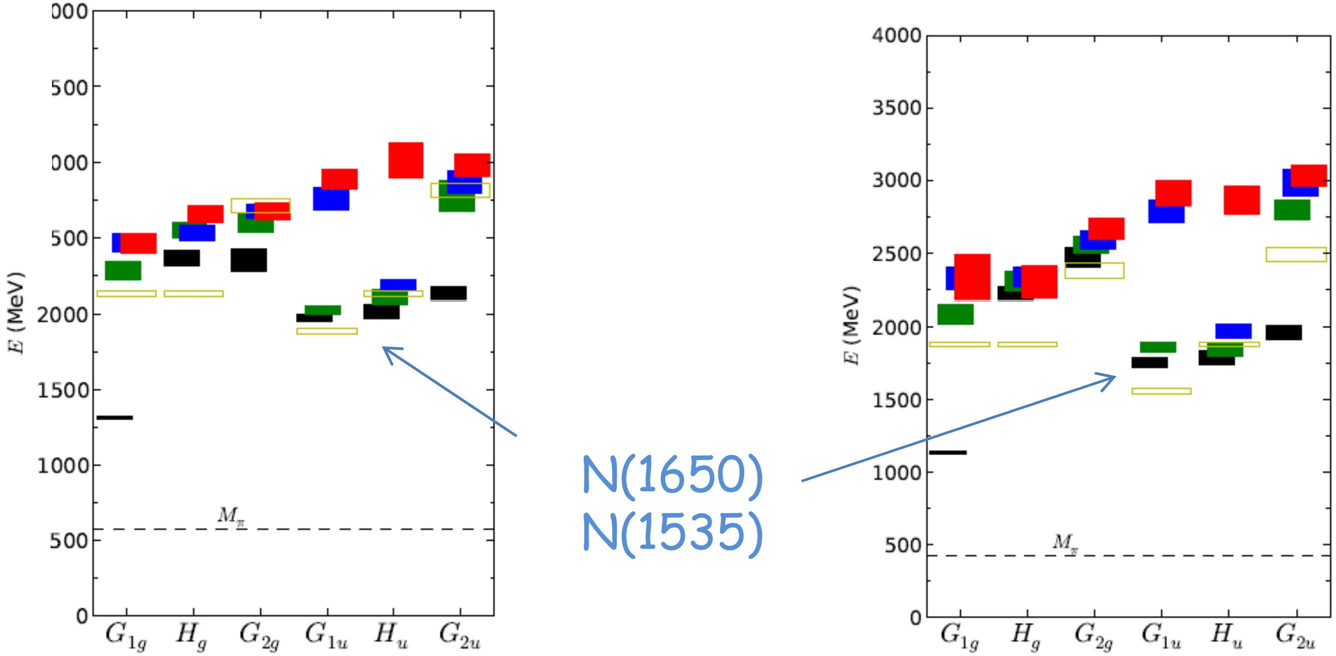
10% $qqqq\bar{q}$ admixture in Δ wavefunction

increases the calculated pion decay width by
factors 2-3 over qqq model result
(Q.B.Li & DOR, PRC 73, 035201 (2006)

THE N(1440) ½⁺ AND N(1535) ½⁻ RESONANCES



Present dynamical lattice calculations do not yield the low positive parity resonance



J.Bulava et al,
J.Phys.Conf. Ser. 180
2009,012067

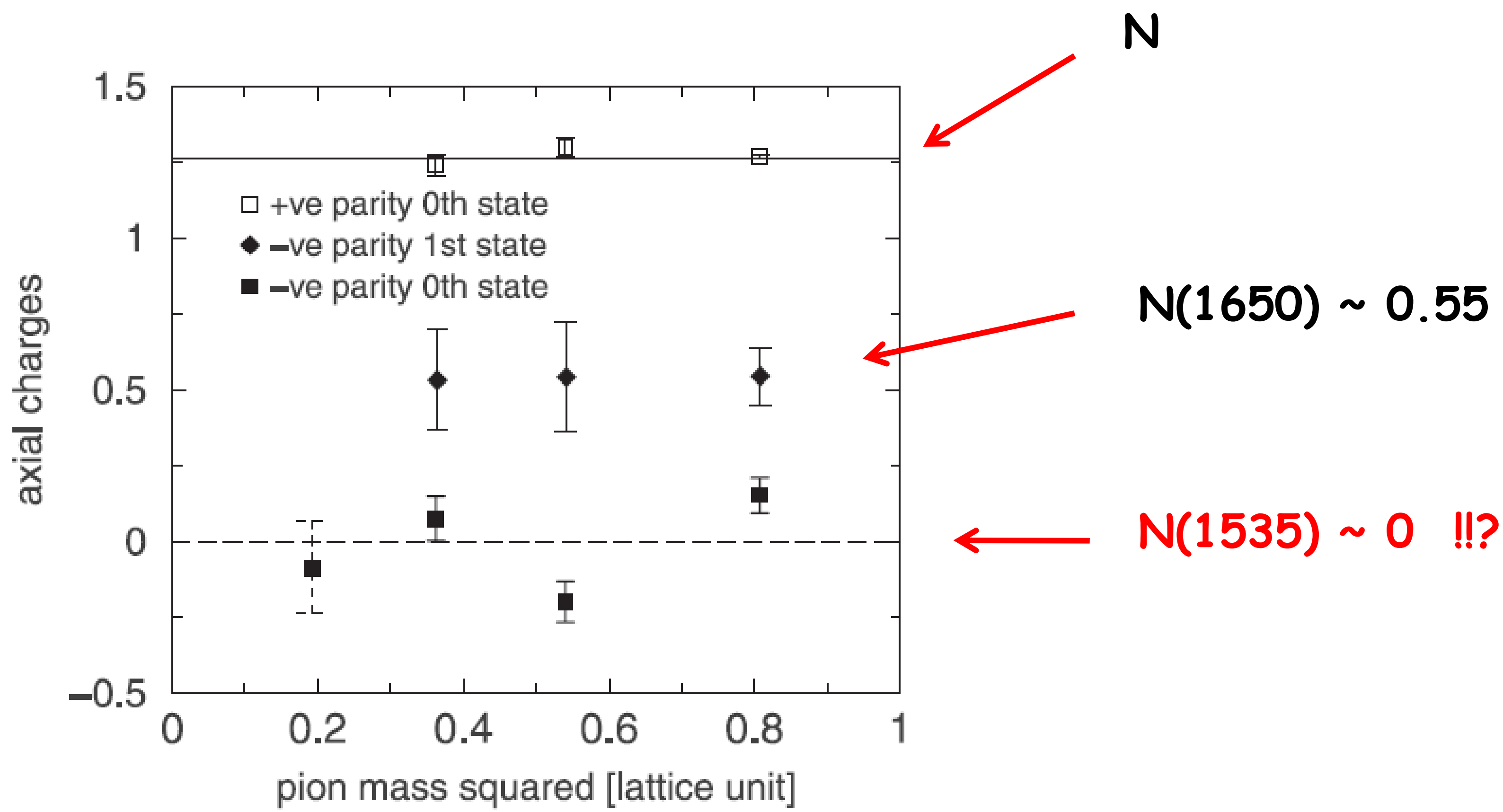
PHYSICAL REVIEW D **79**, 034505 (2009)

Figure 3. The left- and right-hand panels show the spectrum of $I = 1/2$ baryon resonance, indicated by the solid boxes, obtained on $N_f = 2$ Wilson fermion lattices at $m_\pi = 578$ and 416 MeV respectively[7]; the errors are indicated by the vertical width of the box. The open boxes show the expected thresholds for multiparticle states.

AXIAL CHARGE OF N(1535)

Toru T. Takahashi and Teiji Kunihiro

PHYSICAL REVIEW D **78**, 011503(R) (2008)



Quark model expectations:

$$\frac{1}{2}^{+}, N(1440): \quad G^A = \frac{5}{3},$$

= N(939)

$$\frac{1}{2}^{+}, N(1710): \quad G^A = \frac{1}{3},$$

$$\frac{1}{2}^{-}, N(1535): \quad G^A = -\frac{1}{9},$$

untypically small – not that far from lattice value ~ 0

$$\frac{1}{2}^{-}, N(1650): \quad G^A = \frac{5}{9}.$$

Excellent agreement with lattice value 0.55

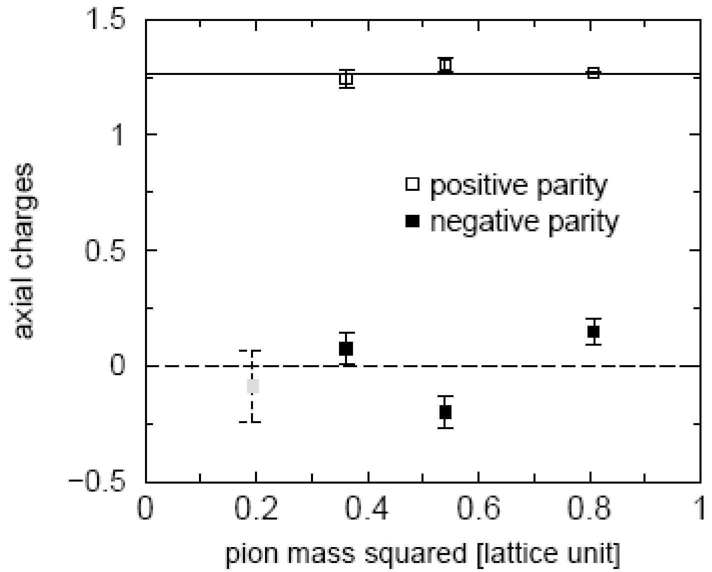
L.Ya. Glozman[a,*], A.V. Nefediev

Nuclear Physics A 807 (2008) 38–47

AXIAL CHARGE:
Non-diagonal terms suppressed !

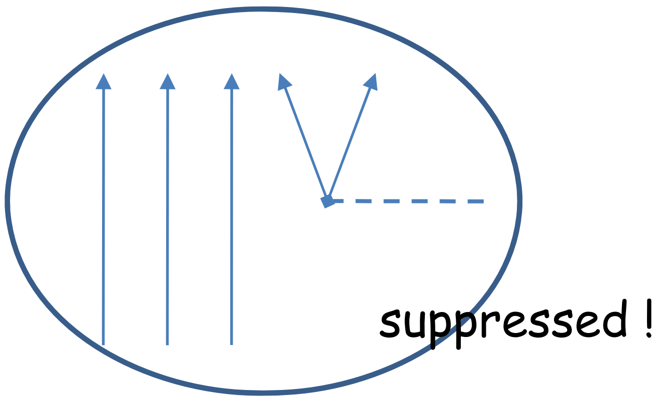
Axial charge of N(1535) in lattice QCD

Toru T. Takahashi and Teiji Kunihiro



$$g_A^* \simeq \sum_n A_n P_n$$

N = 3, 5, 7, ...

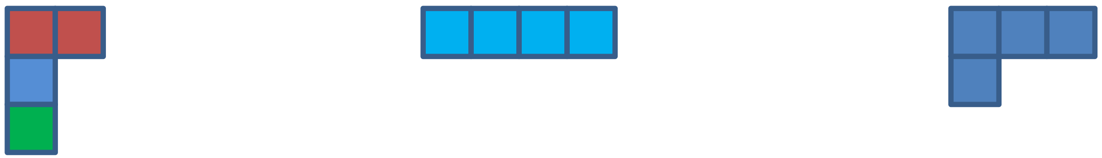


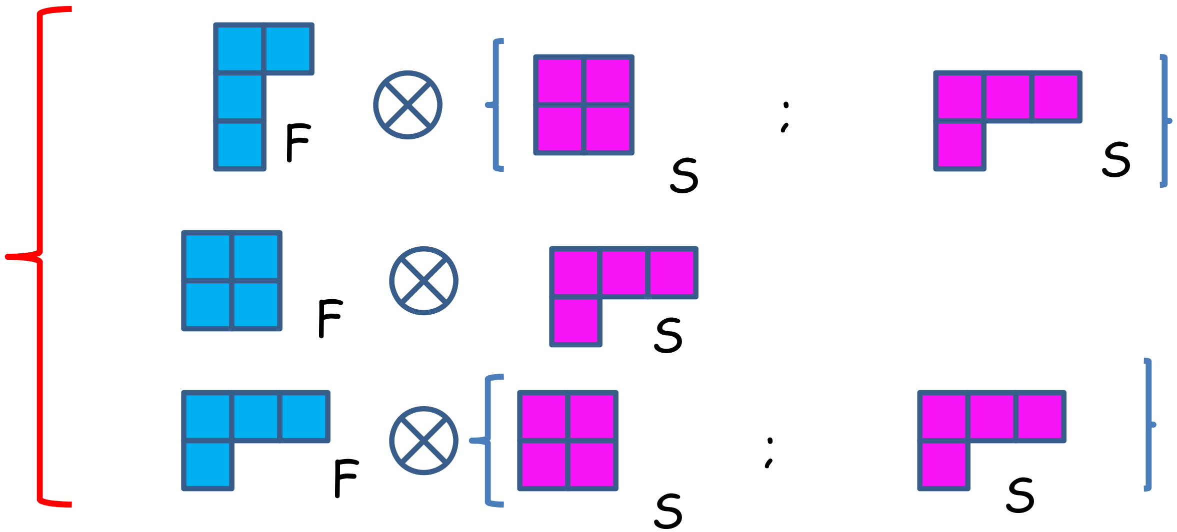
$g_A(N(1535))_{qqq}$ = - 1/9

$g_A(N(1535))_{qqqq\bar{q}}$ = ?

qqqq configurations in the N(1535) [antiquark in S-state]

COLOR: [211]; SPACE: [4]; FLAVOR-SPIN: [31]





One quark strange !

5 configurations in all

C.S.An & DOR, Eur Phys J A 37 (2008) 263

$$g_A^* \simeq \sum_n A_n P_n$$

configuration	flavor-spin	C_{FS}	color-spin	C_{CS}	A_n
1	$[31]_{FS}[211]_F[22]_S$	-16	$[31]_{CS}[211]_C[22]_S$	-16	0
2	$[31]_{FS}[211]_F[31]_S$	$-40/3$	$[31]_{CS}[211]_C[31]_S$	$-40/3$	$+5/6$
3	$[31]_{FS}[22]_F[31]_S$	$-28/3$	$[22]_{CS}[211]_C[31]_S$	$-16/3$	$-1/9$
4	$[31]_{FS}[31]_F[22]_S$	-8	$[211]_{CS}[211]_C[22]_S$	0	$-4/15$
5	$[31]_{FS}[31]_F[31]_S$	$-16/3$	$[211]_{CS}[211]_C[31]_S$	$+8/3$	$+17/18$

contains an s quark

$$C_{kS} = -\sum_{i,j} \lambda_i \cdot \lambda_j \sigma_i \cdot \sigma_j$$

~ O(1)

$$g_A(N(1535)) = -\frac{1}{9}P_3 + \frac{5}{6}P_5^{(2)} - \frac{1}{9}P_5^{(3)} - \frac{4}{15}P_5^{(4)} + \frac{17}{18}P_5^{(5)}$$

Cancellation between qqq & $qqqq\bar{q}$ possible !

J.C.Nacher et al, NPA 678 (2000) 187

$$|N^*(1535)\rangle = a|1\rangle - b|2\rangle,$$
$$|N^*(1650)\rangle = b|1\rangle + a|2\rangle.$$

In Fig. 14 we show g_A^* as a function of the mixing coefficient a. We see that depending on the value of a, the coupling constant g_A^* can be either positive or negative. In the successful model by Isgur and Karl [26], the mixing coefficient takes the value $a \sim 0.85$, yielding an axial vector coupling constant $g_A^* \sim 0.87$, which is about an order of magnitude larger than

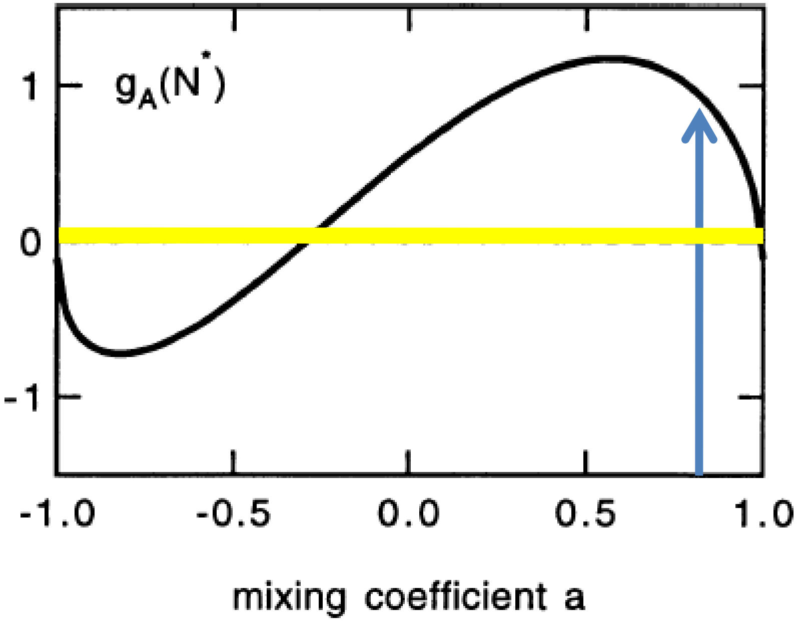
N. Isgur, G. Karl, Phys. Lett. B 72 (1977) 109

$a = \cos \theta_S$

Capstick & Roberts:

$N\pi$ decay: a = 0.79 ..
disagrees with lattice result

$N\eta$ decay: a = 1 ...
agrees with lattice result & quark model without mixing



$$g_A^* = \frac{1}{9}\left(-a^2 + 16a\sqrt{1-a^2} + 5(1-a^2)\right)$$

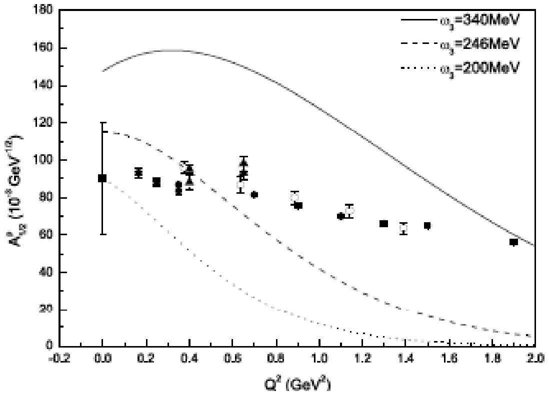
CONFIGURATION MIXING SMALL !

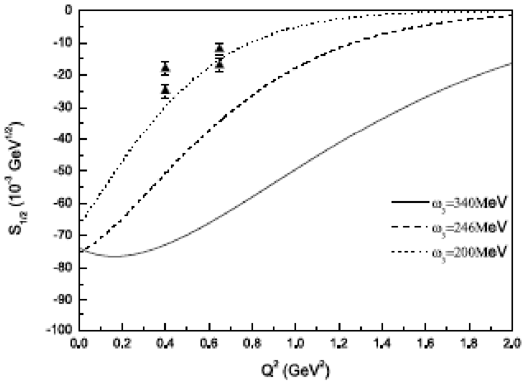
Large N: θ_S = 0 .. 35° D. Pirjol & C. Schat, arXiv: 0906.0802 [hep-ph]

$\gamma N \rightarrow N(1535)$

C.S.An and B.S.Zou
EPJA 39, 195 (2009)

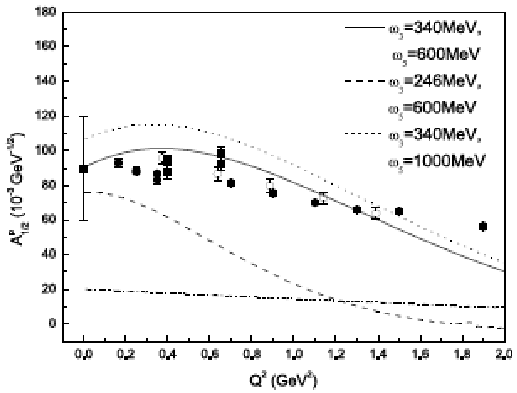
qqq quark model:

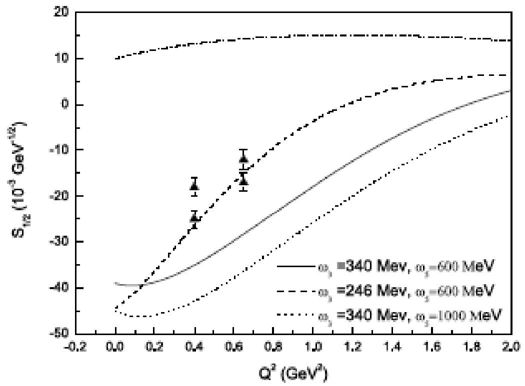




$qqqq\bar{q}$

10% in N,
45% in N*





γ N → N(1440)

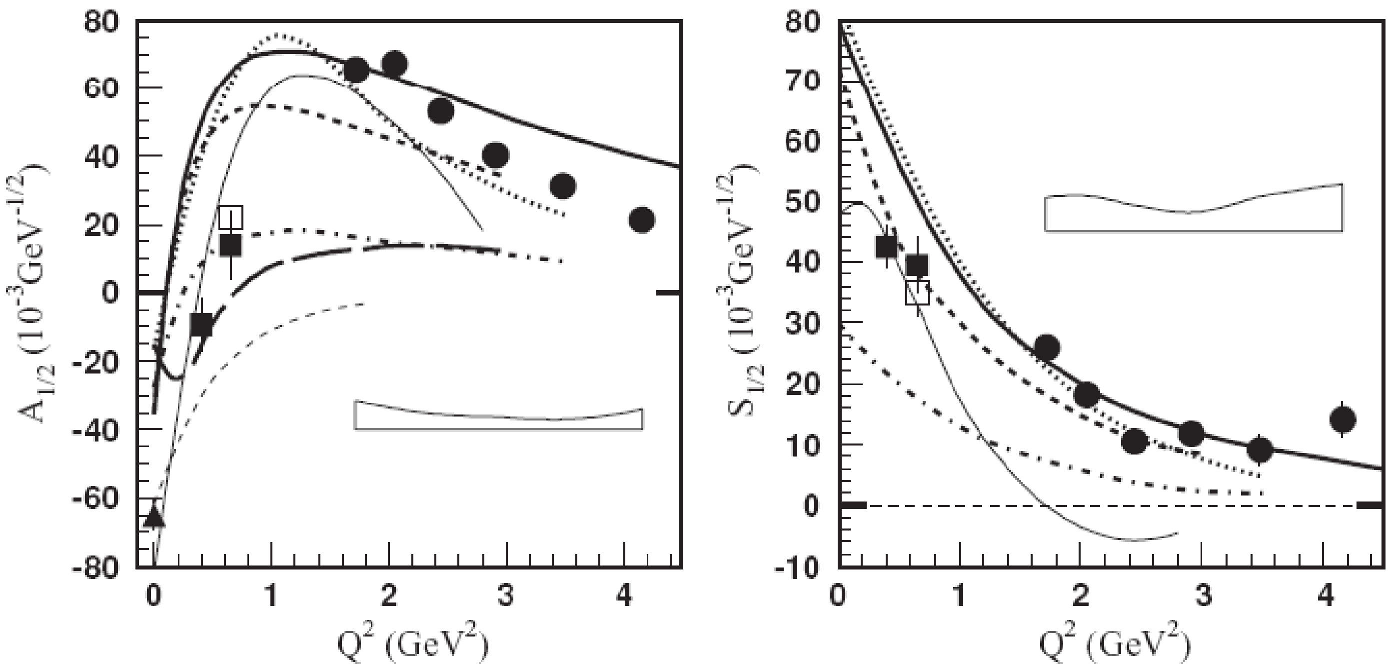


FIG. 2. Helicity amplitudes for the $\gamma^* p \rightarrow$N(1440)P$_{11}$ transition. The full circles are our results obtained from the analysis of π^+ electroproduction data [11]. The bands present the model uncertainties (I,II,III) added in quadrature; see text. The full boxes are the results obtained from CLAS data [13,31,34–36]; open boxes present the results of the combined analysis of CLAS single π and 2π electroproduction data [14]. The full triangle at $Q^2 = 0$ is the RPP estimate [17]. The thick curves correspond to the light-front relativistic quark models: dotted, dashed, dash-dotted, long-dashed, and solid curves are from Refs. [1,37–40], respectively. The thin solid curves are the predictions obtained for the Roper resonance treated as a quark core dressed by a meson cloud [7,8]. The thin dashed curves are obtained assuming that N(1440)P$_{11}$ is a q^3G hybrid state [6].

γ N $\rightarrow$ N(1440) with $qqqq\bar{q}$ components

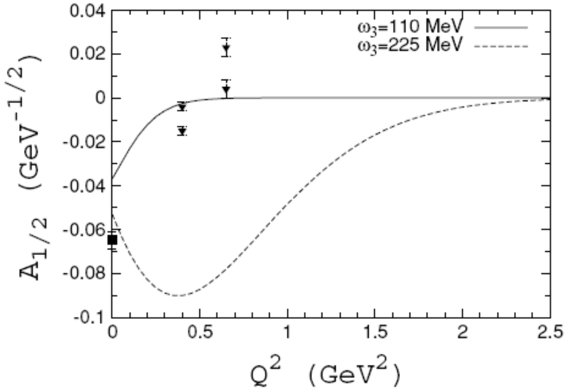
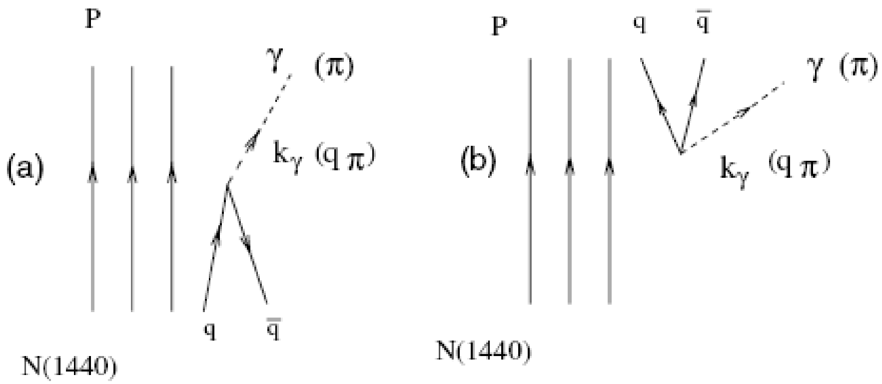


FIG. 1. The helicity amplitude for $N(1440)^+ \rightarrow p\gamma$ in the qqq model for two values of the oscillator frequency ω_3. The data point at $Q^2 = 0$ is from Ref. [7] (square) and the other points are taken from the phenomenological analysis in Ref. [11] (triangles).



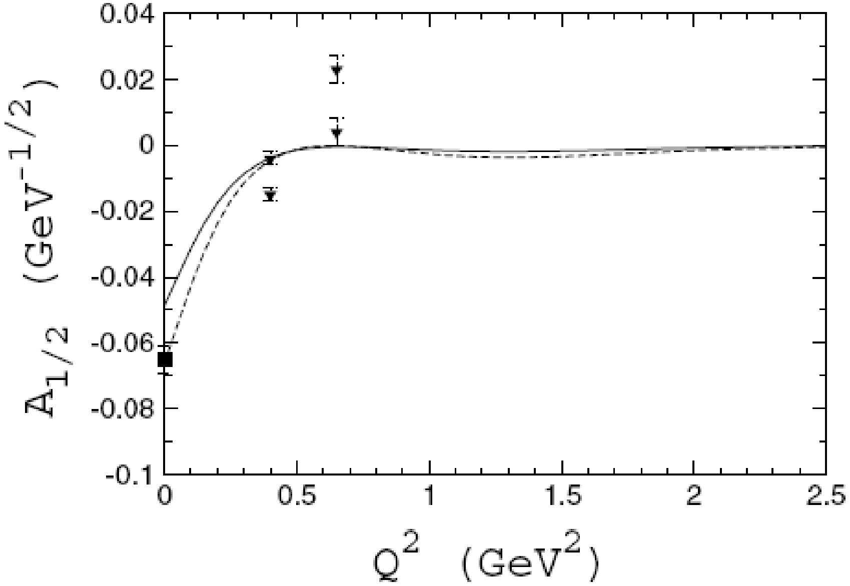


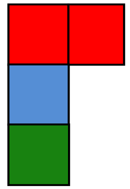
FIG. 5. The helicity amplitude of the decay $N(1440)^+ \rightarrow p\gamma$ as a function of Q^2. (Solid line) Only $[4]_{FS}[22]_F[22]_S$ configuration; (dashed line) both $[4]_{FS}[22]_F[22]_S$ and $[4]_{FS}[31]_F[31]_S$ configurations are considered. Here the probability of the $[4]_{FS}[22]_F[22]_S$ configuration in the $qqqq\bar{q}$ component is taken as be 80%. The data point at $Q^2 = 0$ is from Ref. [7] (square) and the other points are taken from the phenomenological analysis in Ref. [11] (triangles).

Q.B.Li and DOR, PRC C74, 015202 (2006)

$qqqq\bar{q}$ CONFIGURATIONS in the nucleon

qqqq SUBSYSTEM TOTALLY ANTISYMMETRIC

COLOR: [211] MIXED SYMMETRY (only 3 different colors)



“[211]”

SPACE-FLAVOR-SPIN: [31] MIXED SYMMETRY !

EITHER:

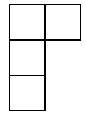
a) SPACE: SYMMETRIC [4],   SPIN-FLAVOR: [31]   antiquark in p-state
   (~ pion cloud configuration)

OR

b) SPACE: MIXED SYM: [31], SPIN-FLAVOR: [4]   antiquark in s-state
[31]
[22]

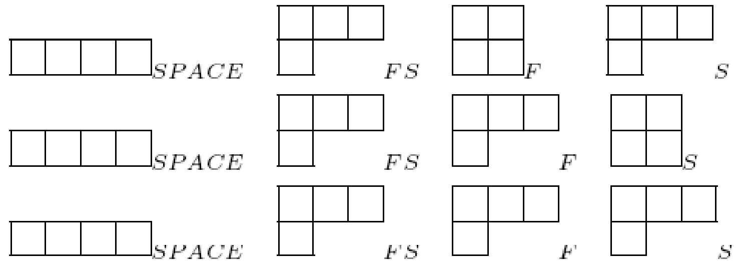
$qqqq\bar{q}$ configurations in the nucleon

Most antisymmetric $qqqq$ system color configuration:



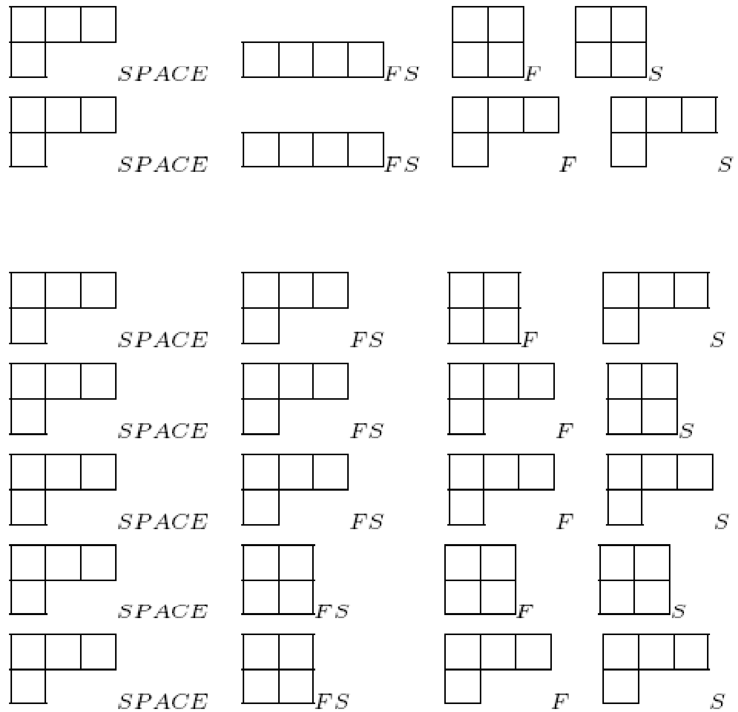
$[211]_C$

antiquark in $P-$state:



(1)
(2)
(3)

antiquark in $S-$state:



(4)
(5)
(6)
(7)
(8)
(9)
(10)

$qqqq\bar{q}$ configurations in the nucleon

Antiquark in the s-state:

	magnetic moment		
	p	n	
$[4]_{\{FS\}}\,[22]_F\,[22]_S$	0	1/3	$(m_p/m_Q)\,\mu_N$
$[4]_{\{FS\}}\,[31]_F\,[31]_S$	2/9	-2/9	(J=1: qqqq)
	-1/3	0	(J=0:qqqq)

Antiquark in the p-state

	p	n	
$[31]_{\{FS\}}\,[22]_F\,[31]_S$	7/27	-23/27	$q\ \ j = 3/2$
	-4/27	0	$q\ \ j = 1/2$
$[31]_{\{FS\}}\,[31]_F\,[22]_S$	-2/9	0	
$[31]_{\{FS\}}\,[31]_F\,[31]_S$	-19/27	1/9	

A single $qqqq\bar{q}$ component does not describe the nucleon magnetic moment !

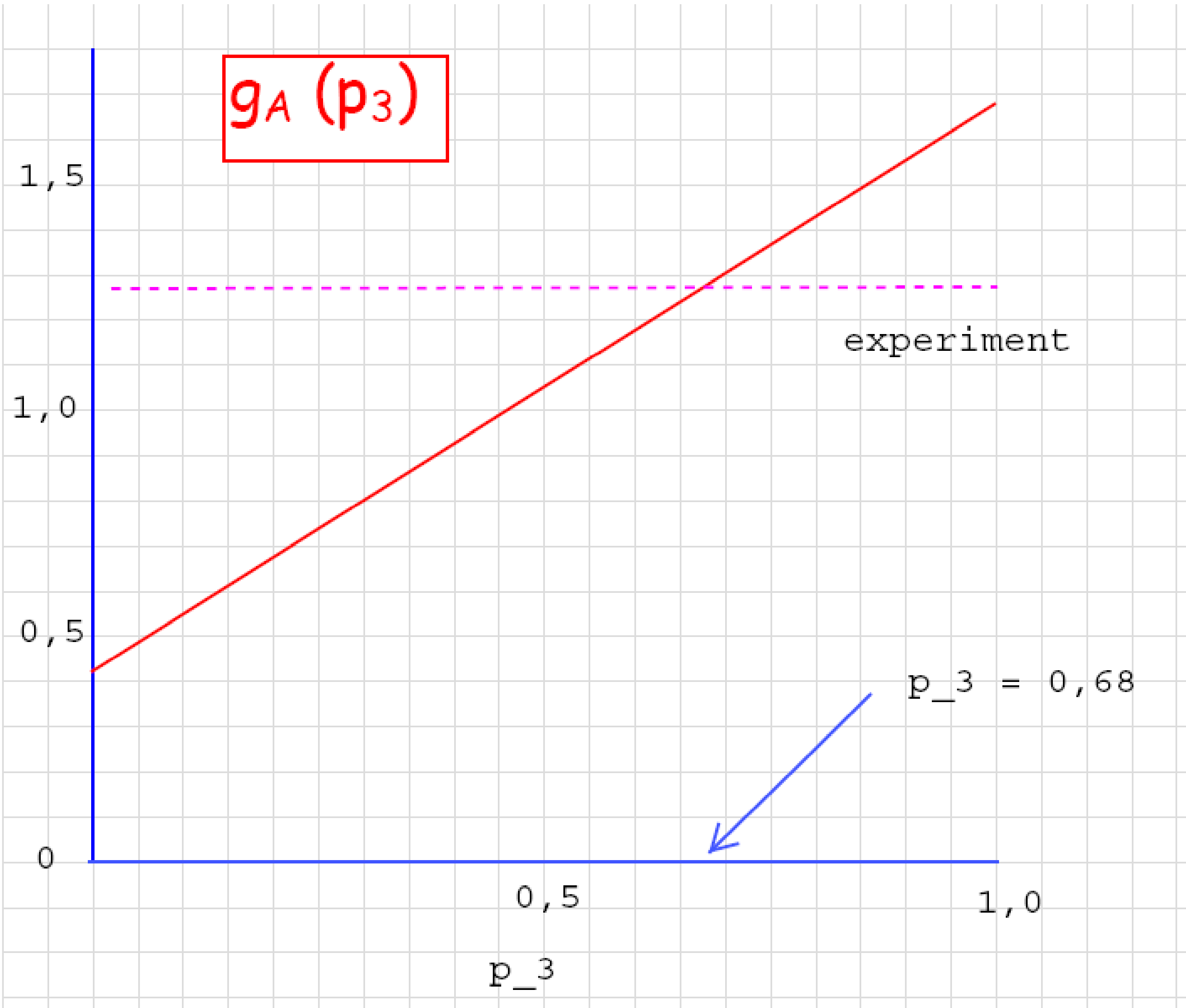
A linear combination of the configurations [4][22][22] and [4][31][31]$^{J=1}$ and [4][31][31]$^{J=0}$ describes the magnetic moments

$$\psi = \sqrt{p_3}\varphi_{[3][21][21]} + \sqrt{\frac{p_5}{\frac{11}{9}b_1 + \frac{5}{3}b_2}}\{\sqrt{\frac{2}{9}b_1 + \frac{2}{3}b_2}\varphi_{[4][22][22]}$$
$$+\sqrt{b_1}\varphi^{J=1}_{[4][31][31]} + \sqrt{b_2}\varphi^{J=0}_{[4][31][31]}\}$$

$$\mu_p = -\frac{3}{2}\mu_n$$ holds for all nonzero values of b_1 and b_2

$$g_A = -\frac{5}{3}\{p_3 + \frac{3}{5}\frac{23b_1 + 9b_2}{33b_1 + 45b_2}p_5\}$$

$$|g_A| \leq |g_A(qqq)|$$



$g_A\ (p_3)$
1,5
1,0
0,5
0
experiment
p_3 = 0,68
0,5
1,0
p_3

“LOWEST CONFIGURATION ONLY”, INCLUDING CROSS TERMS

C.S.An et al, PR C 74, 055205 (2006), PRC C 75, 069901 (2007)

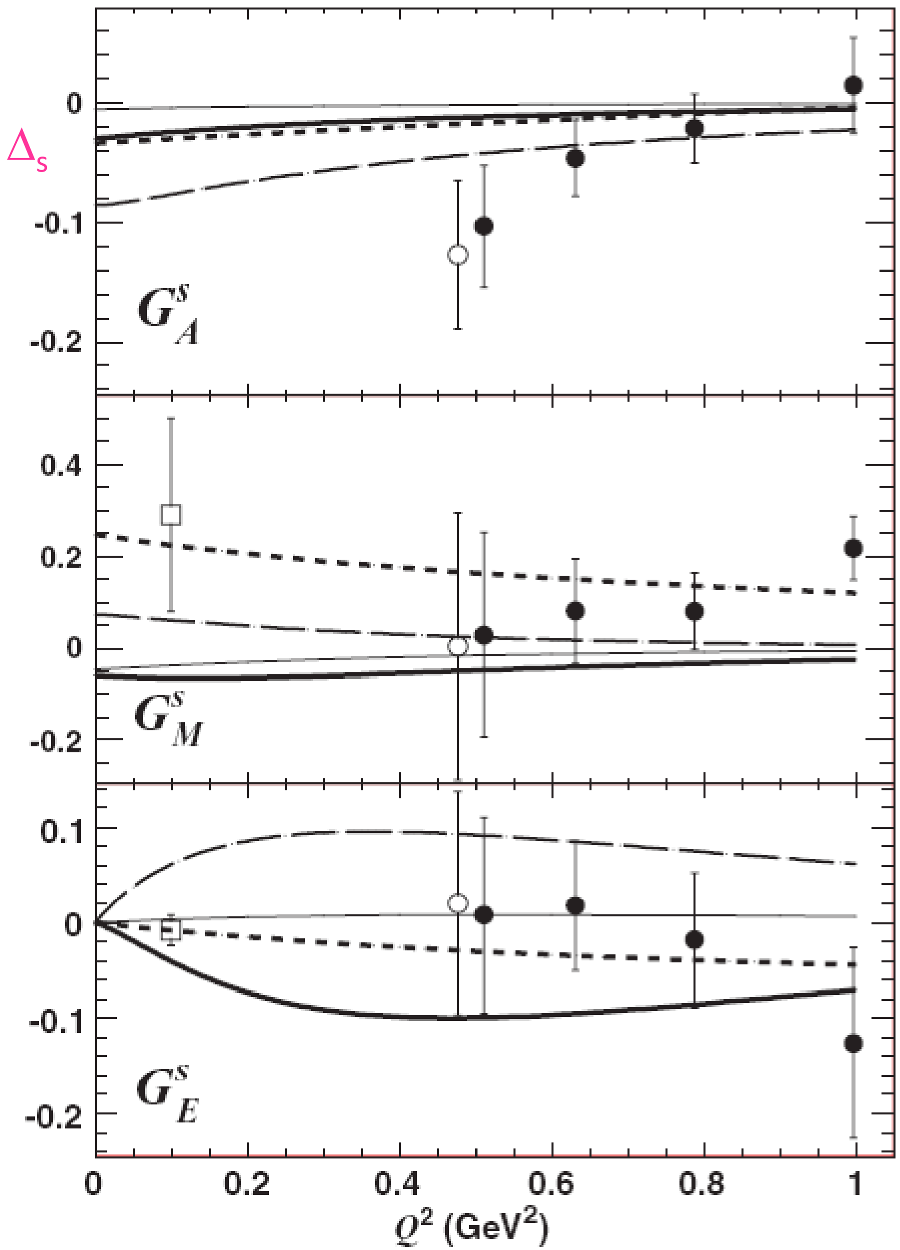
$$[4]_{FS}[22]_F[22]_S \; : \; \square\square\square\square_{FS}\; \begin{smallmatrix}\square\square\\ \square\square\end{smallmatrix}_F\; \begin{smallmatrix}\square\square\\ \square\square\end{smallmatrix}_S \,,$$ octet

$$[4]_{FS}[31]_F[31]_S \; : \; \square\square\square\square_{FS}\; \begin{smallmatrix}\square\square\square\\ \square\end{smallmatrix}_F\; \begin{smallmatrix}\square\square\square\\ \square\end{smallmatrix}_S$$ decuplet

INCLUDES qqq-qqqq$\bar{q}$
CROSS TERMS

Baryon	Exp	P_1	P_2	P_3	P_4
p	2.79	2.72	3.01	2.40	2.76
n	-1.91	-1.66	-1.91	-1.34	-1.66
Λ	-0.61	-0.61	-0.68	-0.71	-0.80
Σ^+	2.46	2.63	2.90	2.31	2.65
Σ^0	?	0.76	0.86	0.60	0.735
Σ^-	-1.16	-1.11	-1.18	-1.11	-1.18
Ξ^0	-1.25	-1.21	-1.43	-0.89	-1.18
Ξ^-	-0.65	-0.58	-0.60	-0.58	-0.60
$\Sigma^0 \to \Lambda$	$\|1.61\|$	-1.67	-1.84	-2.12	-2.19

UNSATISFACTORY
PHENOMENOLOGY



THE STRANGENESS FORM FACTORS

Combined analysis of data from the G0, HAPPEx, and Brookhaven E734

S. Pate et al.

PHYSICAL REVIEW C **78**, 015207 (2008)

FIG. 1. Results of this analysis for the strange vector and axial form factors of the proton. Open circles are from a combination of HAPPEx and E734 data, whereas the closed circles are from a combination of G0 and E734 data. [Open squares at $Q^2 = 0.1$ GeV^2 are from Ref. [30] and involve parity-violating elastic electron-scattering data only.] The theoretical curves are from models that calculate all three of these form factors: Park and Weigel [45] (thick solid line); Lyubovitskij, Wang, Gutsche, and Faessler [46] (thin solid line); Silva, Kim, Urbano, and Goeke [47–49] (long-dashed line); and Riska, An, and Zou [50–52] (short-dashed line).

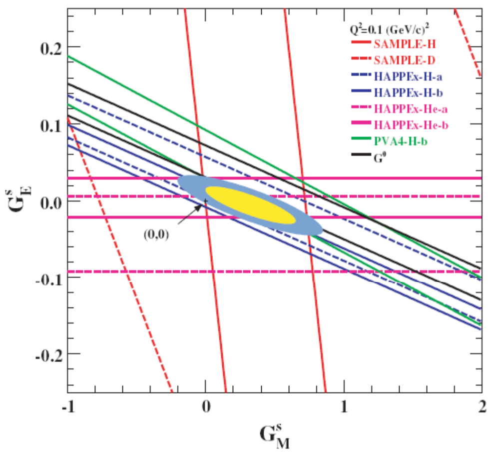
Recent lattice calculations

R. Lewis et al., PRD 67, 013003 (2003)

$$G_M^{(s)}(q_1^2) = \begin{cases} 0.14 \pm 0.29 \pm 0.31, & \text{Ref. [1]}, \\ 0.05 \pm 0.06, & \text{this work}, \end{cases}$$

$$G_E^{(s)}(q_2^2) + 0.39 G_M^{(s)}(q_2^2) = \begin{cases} 0.025 \pm 0.020 \pm 0.014, & \text{Ref. [2]}, \\ 0.07 \pm 0.05, & \text{this work}, \end{cases}$$

PHYSICAL REVIEW C 76, 025202 (2007)

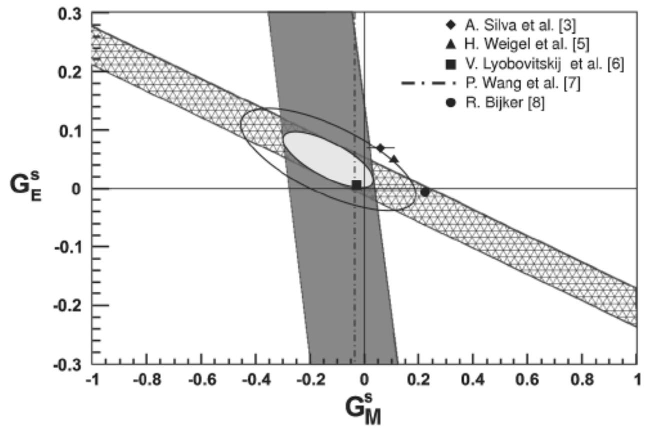


P. Wang et al., PRC 79, 065202 (2009)

$$G_M^s = -0.034 \pm 0.021\,\mu_N$$
$$Q^2 = 0.23\ \mathrm{GeV}^2,$$

D. Leinweber et al., PRL 97, 022001 (2006)

$$G_E^s(0.1\ \mathrm{GeV}^2) = +0.001 \pm 0.004 \pm 0.004$$
$$Q^2 = 0.1\ \mathrm{GeV}^2$$

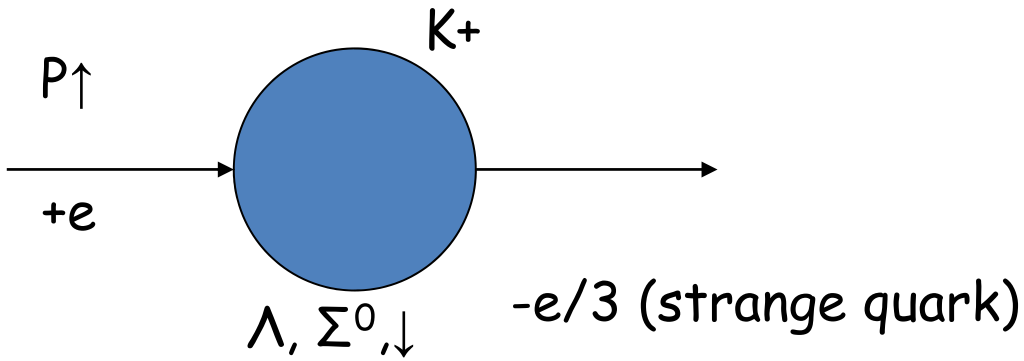


A4

$\mu_s = G_M^s(0)$ SHOULD BE NEGATIVE !

ASYMMETRIC LONG RANGE FLUCTUATION

... PSEUDOSCALAR MESON LOOP



$$\langle K^+ \Lambda^0 | T | p \rangle \sim \langle | \sigma \cdot q | \rangle$$

POSITIVE MAGNETIC MOMENT CONTRIBUTION ?

NO ... MULTIPLY BY – 3 $(\langle s^- | \gamma_\mu | s \rangle)$

NEGATIVE G_M^s !

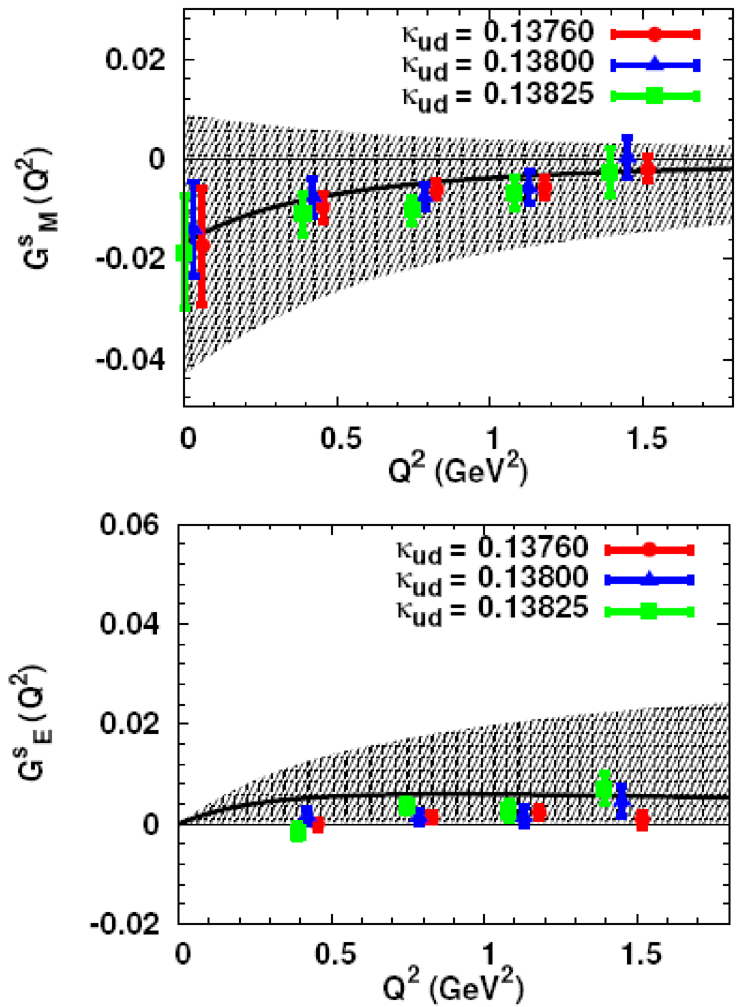


FIG. 3: The chiral extrapolated results for $G^s_M(Q^2)$ (upper) and $G^s_E(Q^2)$ (lower) plotted with solid lines. Shaded regions represent the error-band with statistical and systematic error added in quadrature. Shown together are the lattice data (and Q^2-extrapolated $G^s_M(0)$) for $\kappa_{ud} = 0.13760$ (circles), 0.13800 (triangles), 0.13825 (squares) with offset for visibility.

$N_f = 2 + 1$ clover fermion lattice QCD

T. Doi et al, arXiv: 0903.3232

$$G^s_M(0) = -0.017(25)(07)$$

$$G^s_E(Q^2) = 0.0022(19) \text{ at } Q^2 = 0.1\text{GeV}^2$$

$\bar{s}$ in P-state

TABLE I. Flavor and spin configurations of *uuds* quark states in the ground state [28] and the corresponding operator matrix elements.

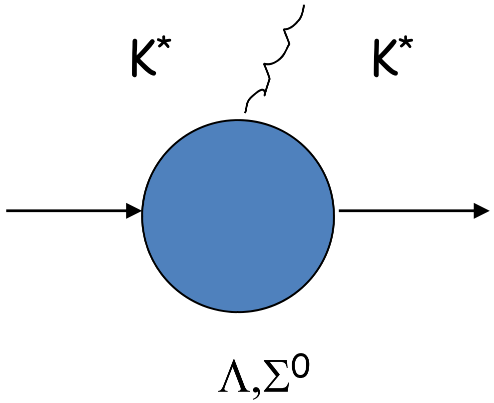
uuds ground state	$\bar{\sigma}_s$	$\Delta_s(P_{s\bar{s}})$	$\mu_s(\frac{m_p}{m_s}P_{s\bar{s}})$	$-CC_2^{(6)}$
$[31]_{FS}[211]_F[22]_S$	–	$\boxed{-1/3}$	$\boxed{-1/3}$	$-16C$
$[31]_{FS}[211]_F[31]_S$	13/36	85/216	−95/216	$-13\frac{1}{3}C$
$[31]_{FS}[22]_F[31]_S$	1/2	5/12	−5/12	$-9\frac{1}{3}C$
$[31]_{FS}[31]_F[22]_S$	–	$\boxed{-1/3}$	$\boxed{-1/3}$	$-8C$
$[31]_{FS}[31]_F[31]_S$	65/108	281/648	−259/648	$-5\frac{1}{3}C$
$[31]_{FS}[31]_F[4]_S$	–	1/6	7/6	0

These correspond to the KΛ loop   h.f. energy

B.S.Zou & DOR, PRL 95, 072001 (2005)

IF POSITIVE G_M^s

VECTOR MESON LOOPS:

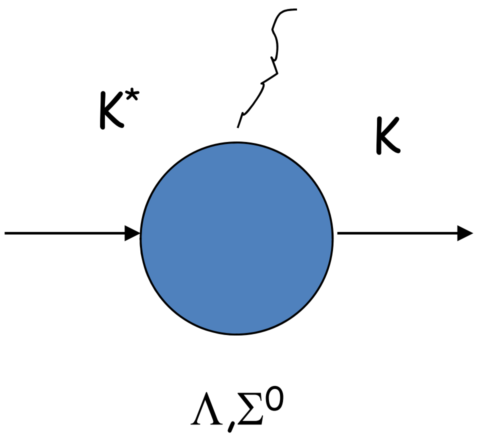


Charge coupling: γ_0 spin non flip,

POSITIVE !

Current coupling: γ : spin-flip

NEGATIVE



POSITIVE !

P. Geiger & N. Isgur
PRD 55, 299 (1997)

$\bar{s}$ in the S-state

TABLE II. Flavor and spin configurations of the *uuds* quark states in the first orbitally excited state [28] with total angular momentum $J = 1$ and the corresponding operator matrix elements.

uuds *P* state	$\bar{l}_s$	$\bar{\sigma}_s$	$\Delta_s(P_{s\bar{s}})$	$\mu_s(\frac{m_P}{m_s}P_{s\bar{s}})$	$-CC_2^{(6)}$
$[4]_{FS}[22]_F[22]_S$	1/4	–	−1/3	1/2	$-28C$
$[4]_{FS}[31]_F[31]_S$	1/4	7/9	−2/27	73/108	$-21\frac{1}{3}C$
$[31]_{FS}[211]_F[22]_S$	13/48	–	−1/3	37/72	$-16C$
$[31]_{FS}[211]_F[31]_S$	119/432	13/36	−23/108	707/1296	$-13\frac{1}{3}C$
$[31]_{FS}[22]_F[31]_S$	1/4	1/2	−1/6	7/12	$-7\frac{1}{3}C$
$[31]_{FS}[31]_F[22]_S$	13/48	–	−1/3	37/72	$-8C$
$[22]_{FS}[211]_F[31]_S$	1/4	5/12	−7/36	5/9	$-5\frac{1}{3}$
$[31]_{FS}[31]_F[31]_S$	295/1296	65/108	−43/324	2371/3888	$-5\frac{1}{3}$
$[22]_{FS}[22]_F[22]_S$	1/4	–	−1/3	1/2	$-4C$
$[211]_{FS}[211]_F[22]_S$	11/48	–	−1/3	35/72	0
$[31]_{FS}[31]_F[4]_S$	43/216	–	1/6	497/648	0
$[211]_{FS}[211]_F[31]_S$	119/432	65/108	−43/324	811/1296	$2\frac{1}{3}C$
$[22]_{FS}[31]_F[31]_S$	13/54	5/12	−7/36	251/324	$2\frac{2}{3}C$
$[22]_{FS}[22]_F[4]_S$	1/4	–	1/6	3/4	$4C$
$[211]_{FS}[22]_F[31]_S$	1/4	1/2	−1/6	7/12	$6\frac{2}{3}$
$[211]_{FS}[211]_F[4]_S$	23/72	–	1/6	157/216	$8C$
$[211]_{FS}[31]_F[22]_S$	11/48	–	−1/3	35/72	$8C$
$[211]_{FS}[31]_F[31]_S$	31/144	13/36	−23/108	227/432	$10\frac{2}{3}C$

WHY PENTAQUARKS ?

-BECAUSE CHIRAL SOLITON MODELS PREDICT THEM
AS WELL AS THE LOW LYING PART OF THE HYPERON
SPECTRA AND THE SPLITTING $\Lambda(1405)$-$\Lambda(1520)$

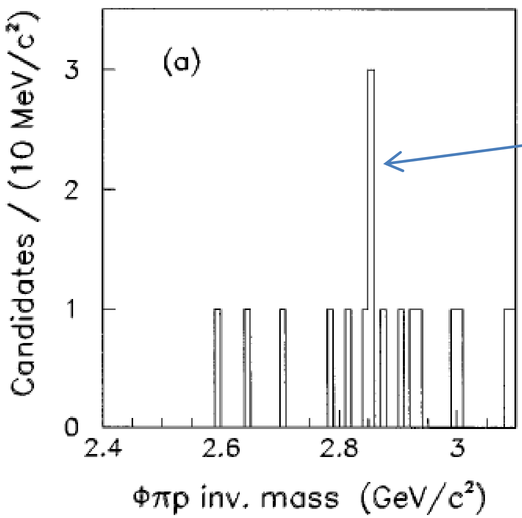
-CONSISTENCY WITH LARGE N_C LIMIT OF QCD

-CHARM & BEAUTY PENTAQUARKS LIKELY TO LIE BELOW
THRESHOLD FOR OPEN CHARM AND BEAUTY DECAY

THE FIRST SEARCH : E791: $P_{\bar{c}s}$

E,M.Aitala et al, PRL 81
44, 303 (1998)

Gignoux, Silvestre-Brac, Richard,
Phys. Lett.B193, 323 (1987)



A few events at
the energy
predicted by the
Skyrme model

Evidence for the Θ^+ in the $\gamma d \rightarrow K^+K^- pn$ reaction by detecting K^+K^- pairs

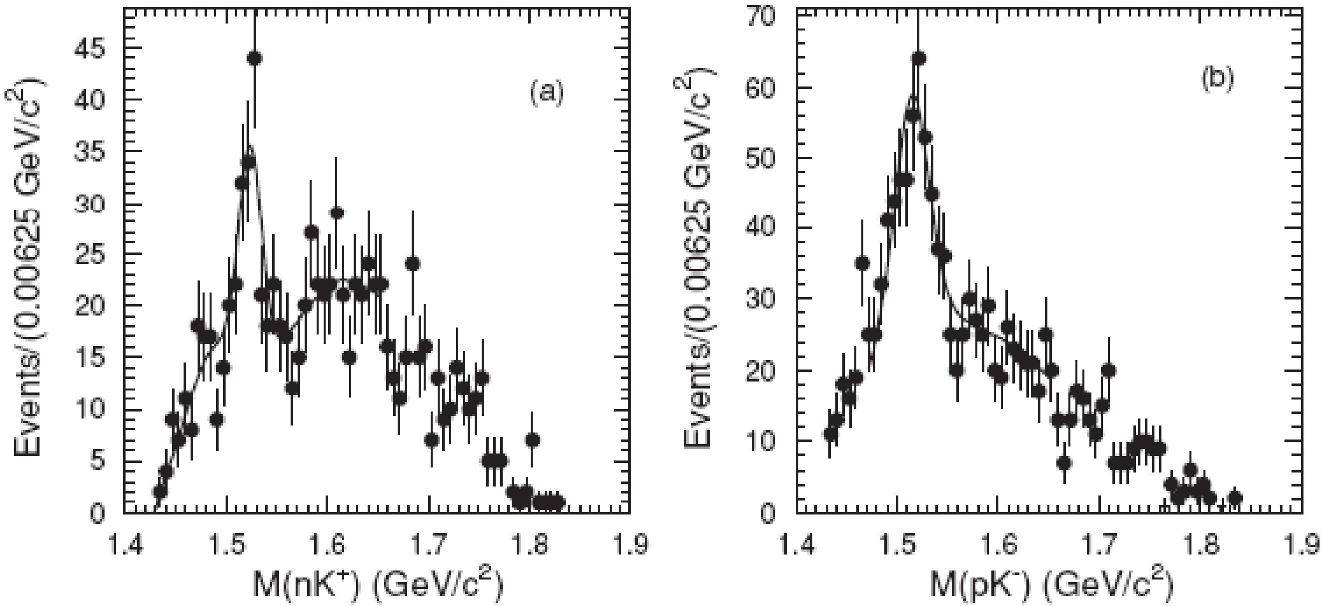


FIG. 16. $M(nK^+)$ (left) and $M(pK^-)$ (right) distributions for events with $M(K^+K^-) > 1.05$ GeV/c^2. The solid lines are fits to the RMM functions plus a Gaussian function.

OPEN QUESTIONS:

WHY NARROW

MULTIPLET ?

q^3 (baryon) and a $q\bar{q}$ (meson)

$$(8)_F \times (8)_F = (27)_F + (10)_F + (\overline{10})_F + 2(8)_F + (1)_F$$

PARITY ± ? All quarks in the S-state

[4]_X : -

$$|1\rangle = ([31]_O[211]_C[1^4]_{OC}; [22]_F[22]_S[4]_{FS})$$

$$|2\rangle = ([31]_O[211]_C[1^4]_{OC}; [31]_F[31]_S[4]_{FS})$$

One of the quarks in the P-state

[31]_X: +

strong hyperfine interaction

Recent and future measurements of

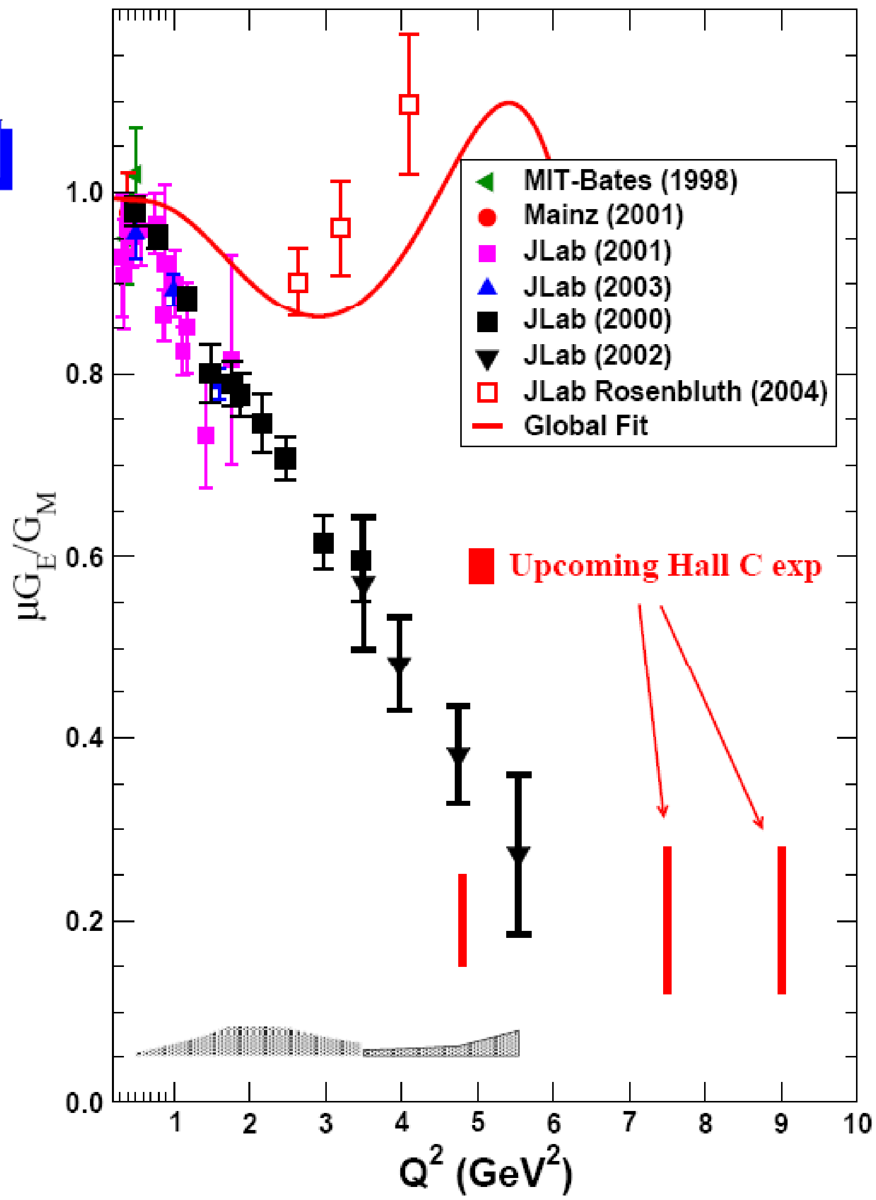
the proton electric form factor

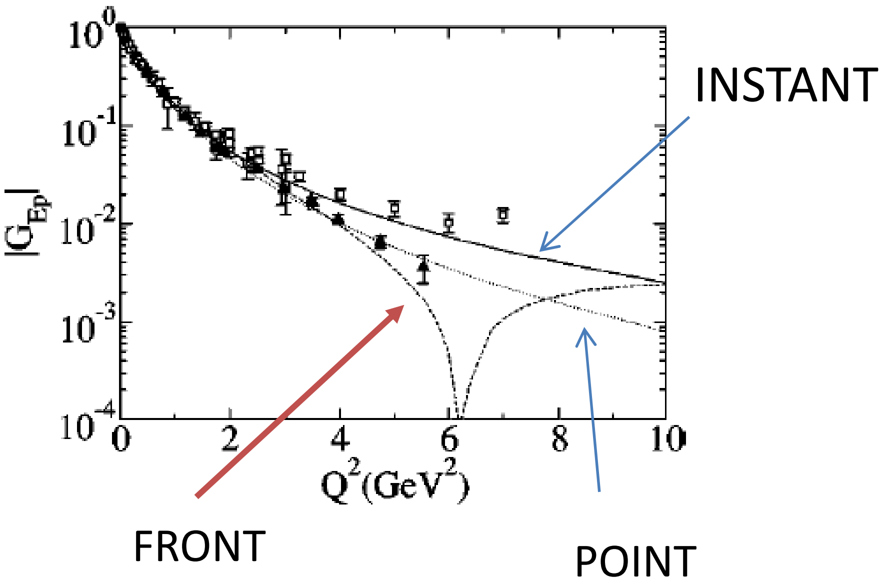
Mark K. Jones, Jefferson Lab

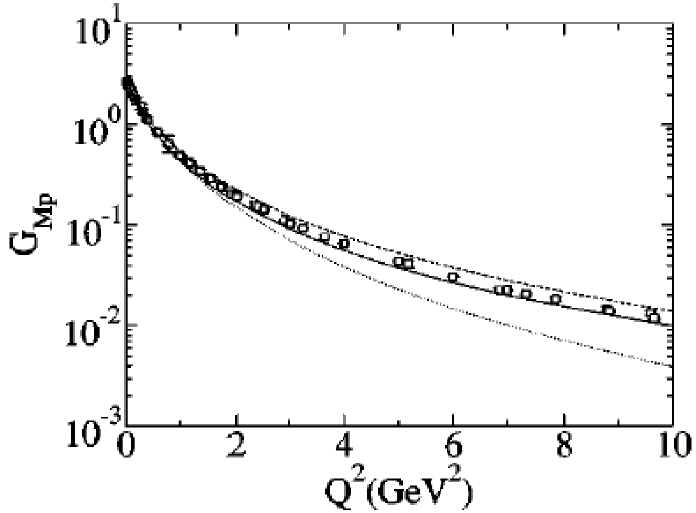
Workshop on Nucleon Form Factors

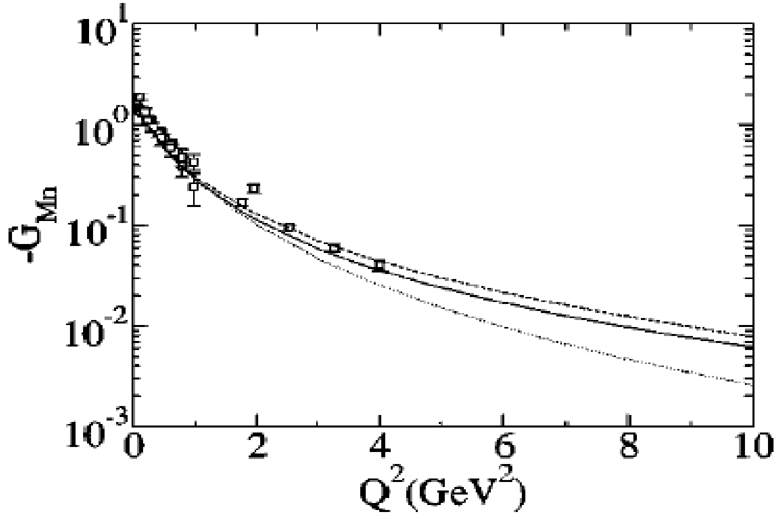
JLAB-PHY-06-13, Nov 2005. 41pp.

NODES IN THE NUCLEON FORM FACTORS ?









IF G_E HAS A NODE, FRONT FORM IS OPTIMAL

B.JULIA-DIAZ et al, PRC C69, 035212(2004)

FORM FACTORS AND $QQQQ\bar{Q}$ CONFIGURATIONS

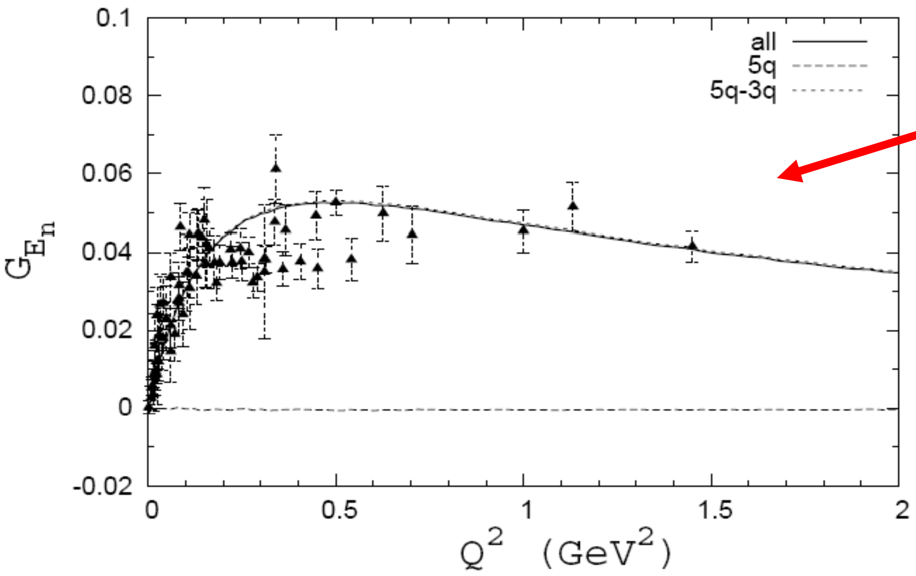
For the spatial wave function model for the $qqqq\bar{q}$ state, for which the spatial wave function of the $qqqq$ subsystem has the mixed symmetry $[31]_X$ the following algebraic form will be employed

$$\varphi_{[31]_a,m}(\{\vec{\xi}_i\}) = \mathcal{N}_{[31]} \frac{\xi_{a,m}}{\left(1 + \frac{(\sum_{j=1}^{4} \vec{\xi}_j^{\,2})}{2B^2}\right)^{(A+1)}}, \quad a = 1, 2, 3. \tag{7}$$

Here $\mathcal{N}_{[31]}$ is a normalization constant. This wave function has the appropriate threshold behavior for a P-state wave function [4]. The analogous wave function for the $qqqq\bar{q}$ state, for which the spatial wave function of the $qqqq$ subsystem is symmetric, and where the $\bar{q}$ is in the P-state, is taken to be

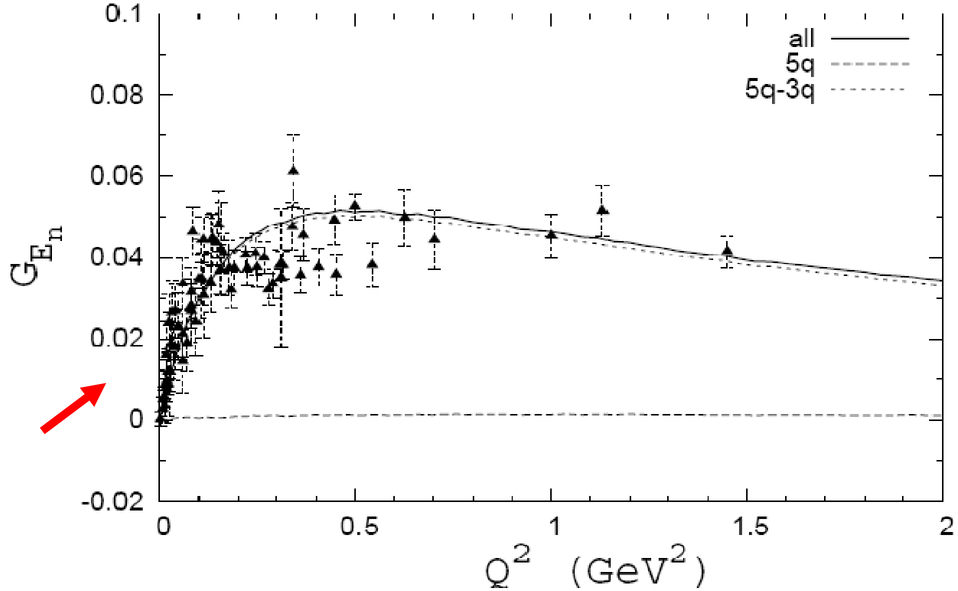
$$\varphi_{[4],m}(\{\vec{\xi}_i\}) = \mathcal{N}_{[4]} \frac{\xi_{4,m}}{\left(1 + \frac{(\sum_{j=1}^{4} \vec{\xi}_j^{\,2})}{2B^2}\right)^{(A+1)}}. \tag{8}$$

$$\vec{\xi}_j = \frac{1}{\sqrt{j + j^2}} \left[\sum_{l=1}^{j} \vec{k}_l - j\vec{k}_{j+1} \right], \quad j = 1, \ldots, n-1$$



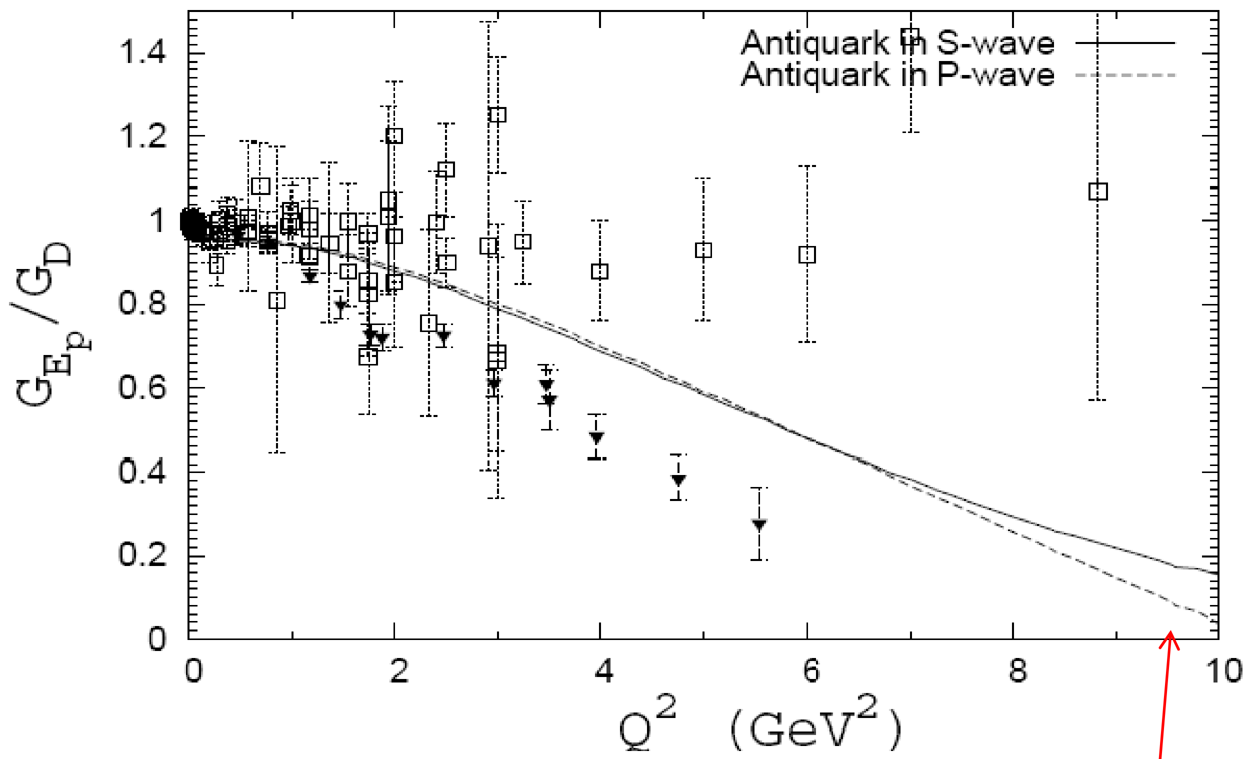
Antiquark in S-state
3% $qqqq\bar{q}$

Large qqq-$qqqq\bar{q}$ matrix elements

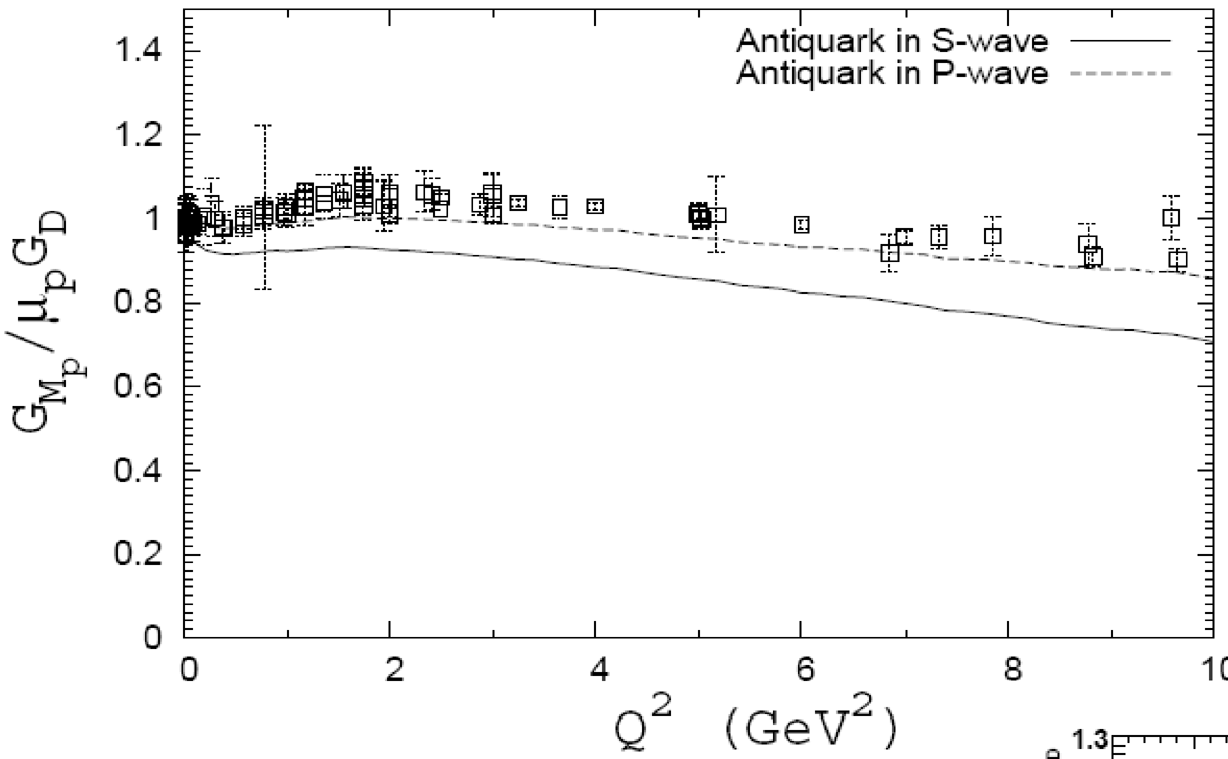


Antiquark in P-state
3% $qqqq\bar{q}$

Qiang-Bing Li & DOR, **Nucl.Phys.A791:406-421,2007**


Antiquark in S-wave
Antiquark in P-wave
G_{E_p}/G_D
Q^2 (GeV^2)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
2
4
6
8
10

Node at 10,5 !



J. Lachniet et al
ArXiv: 0811.1716
nucl/-ex

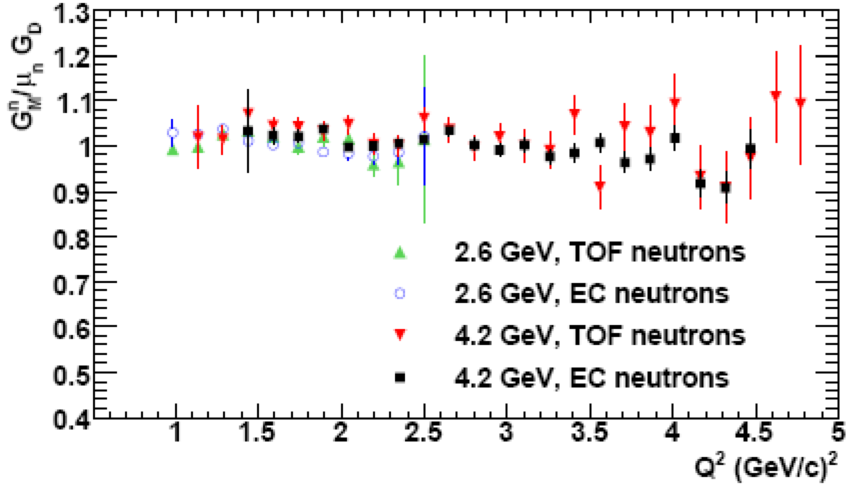
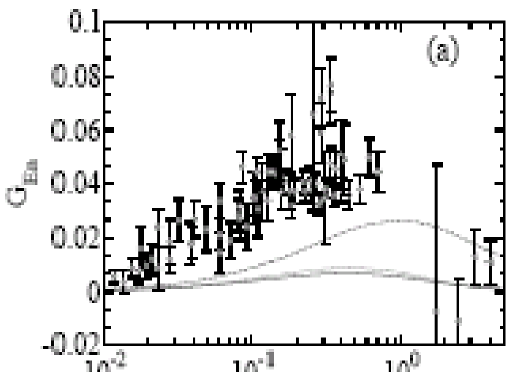
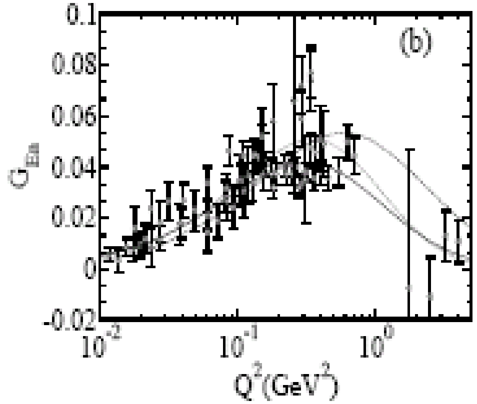


FIG. 2: (color online). Results for $G_M^n/(\mu_n G_D)$ as a function of Q^2 for four different measurements (two beam energies). Only statistical uncertainties are shown.

$G_E(n)$ WITHOUT SEAQUARKS



Symmetric S-state qqq wave function
solid: instant, dotted: point
dashed: front



S': 2% instant,point,
1% front

Consistent quark model demands covariant treatment of the boosts

1-2% mixed symmetry S-state
Sufficient to fix the qqq quark model