CHIRAL SYMMETRY

Chiral symmetry: The π NN coupling should vanish with k_{π}

H. Sugawara & F. Von Hippel:

"ZERO PARAMETER MODEL OF THE N-N POTENTIAL"

Phys. Rev. 172, 1765 (1968)

π, $\pi\pi$ exchange, NΔ, $\Delta\Delta$ intermediate states

R. A. Bryan, B. L. Scott

ONE-BOSON EXCHANGE N-N POTENTIAL

Phys. Rev, 135, B434 (1964)

σ meson, m = 560 MeV

Chiral dynamics baseline:
G.E.Brown & J. W. Durso, PL B 35 B, 120 (1971)

- π, ππ exchange from chiral (LO) Lagrangian:

f_+^0 →

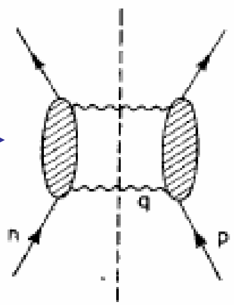


Fig. 1. The two-pion-exchange contribution to the nucleon-nucleon interaction. The wavy lines ~~~ represent pions; the solid lines, nucleons.

PV, chiral coupling

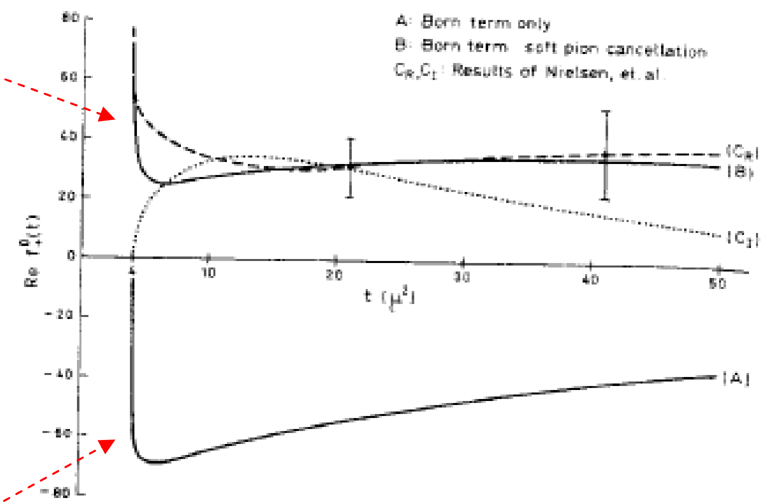
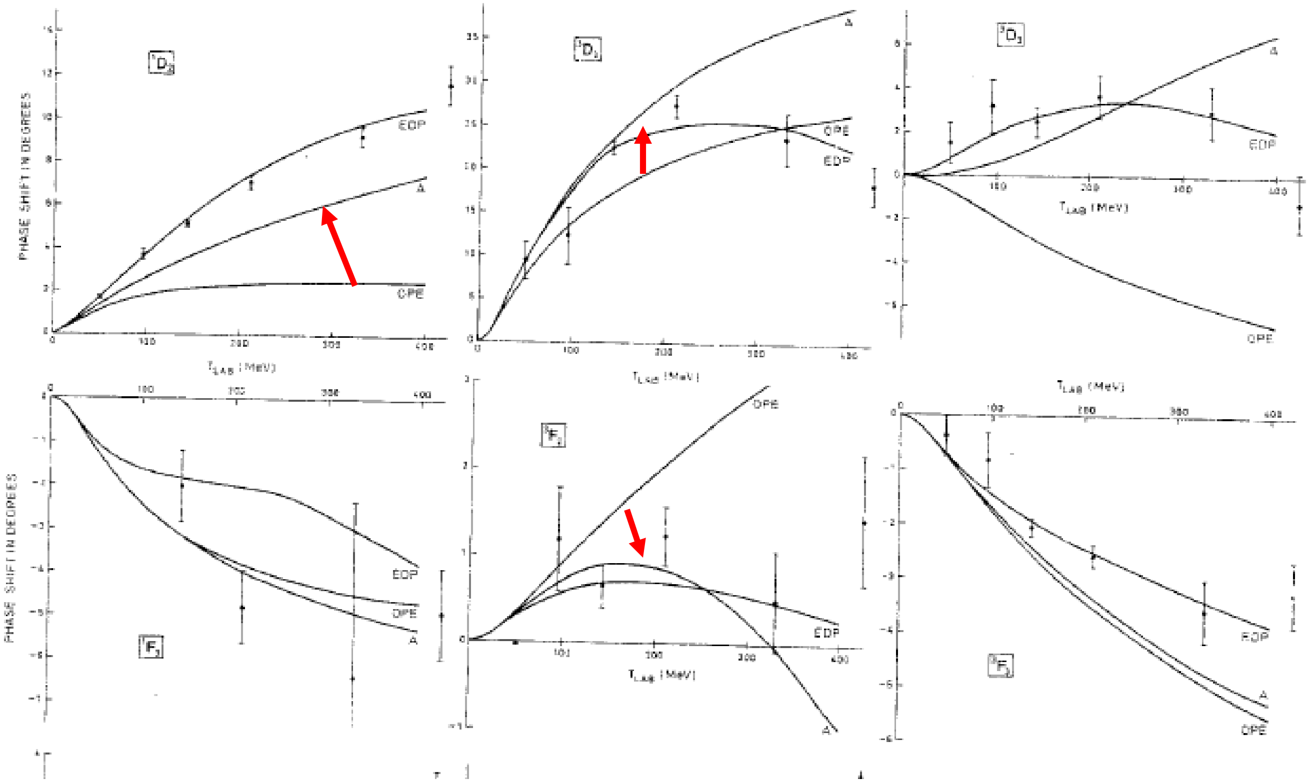
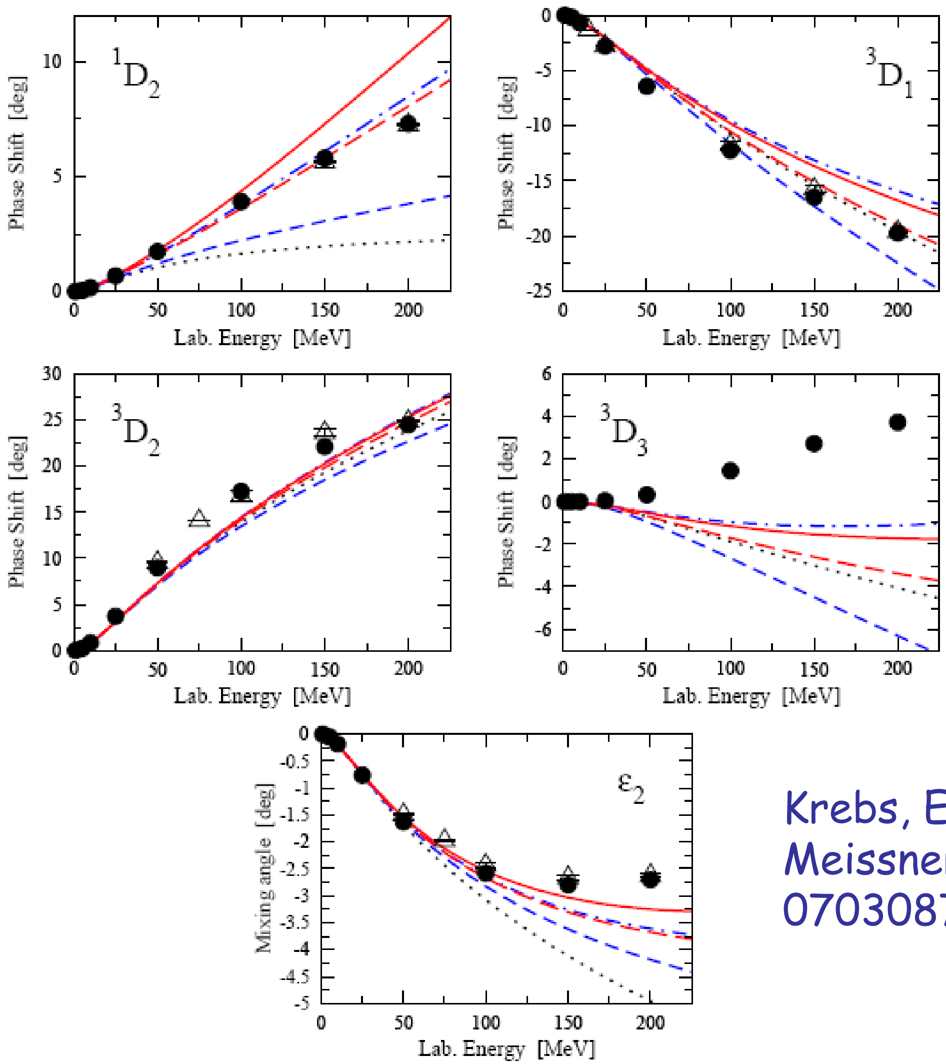


Fig. 2. The f_+^0 obtained from eq. (6) is shown by the solid line ——. The Re f_+^0 and Im f_+^0 obtained in ref. [7] are shown by the dashed ----- and dotted line ....., respectively. Also shown is the f_+^0 obtained from the B^+ of eq. (6.1), neglecting $A^{(+)}$; this is the Born approximation to f_+^0. All amplitudes are plotted in units of the pion Compton wavelength.

Pseudoscalar coupling

NN PHASE SHIFTS

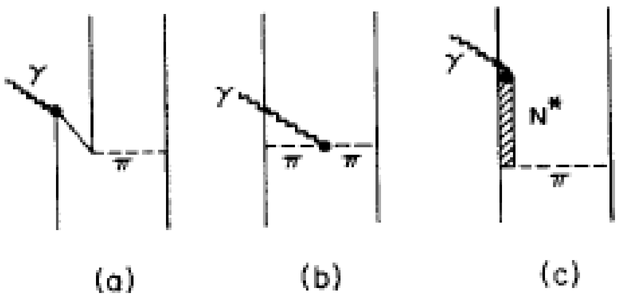




Krebs, Epelbaum & Meissner, nucl-th/0703087

FIG. 7: D–wave NN phase shifts and the mixing parameter ϵ_2. The dotted curve is the LO prediction (i.e. based on the pure OPEP). Long-dashed (short-dashed) and solid (dashed-dotted) lines show the NLO and NNLO results with (without) the explicit Δ-contributions and using the SFR with $\tilde{\Lambda} = 700$ MeV. The filled circles (open triangles) depict the results from the Nijmegen multi–energy PWA [17, 18] (Virginia Tech single–energy PWA [19]).

CHIRAL LONG RANGE PHYSICS



J. Hockert et al,
NPA 217 (1973) 14

LO CHIRAL

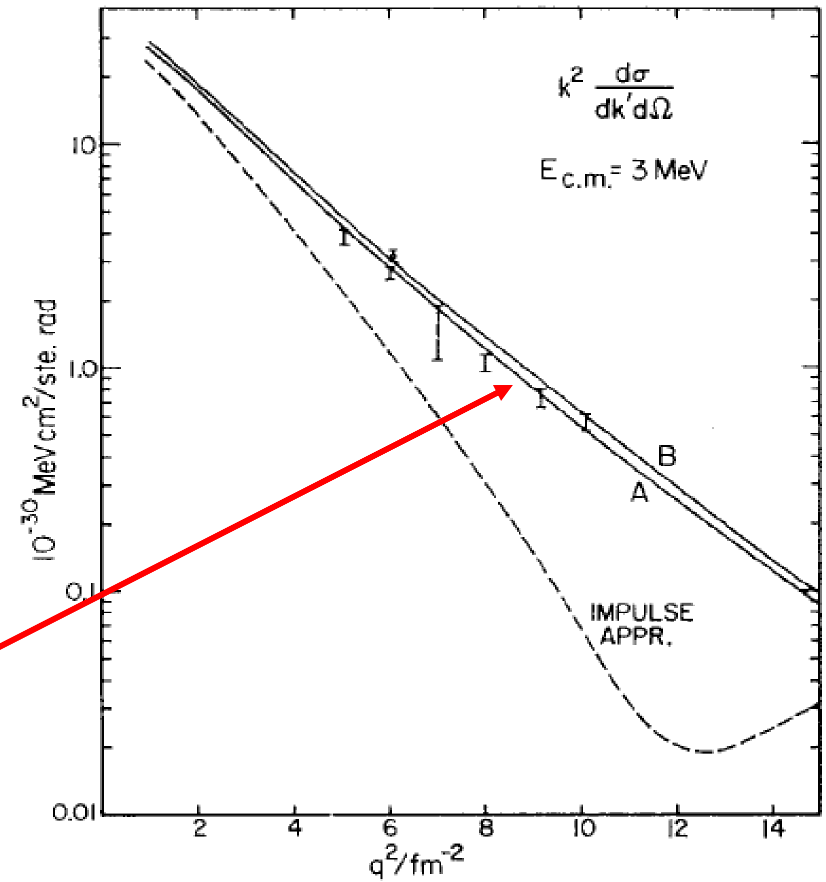
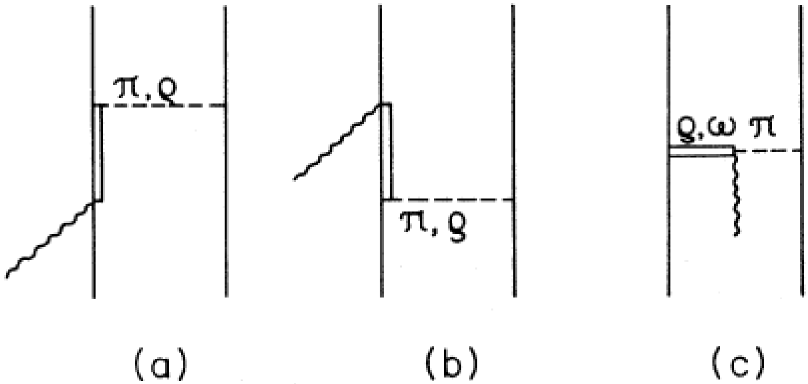
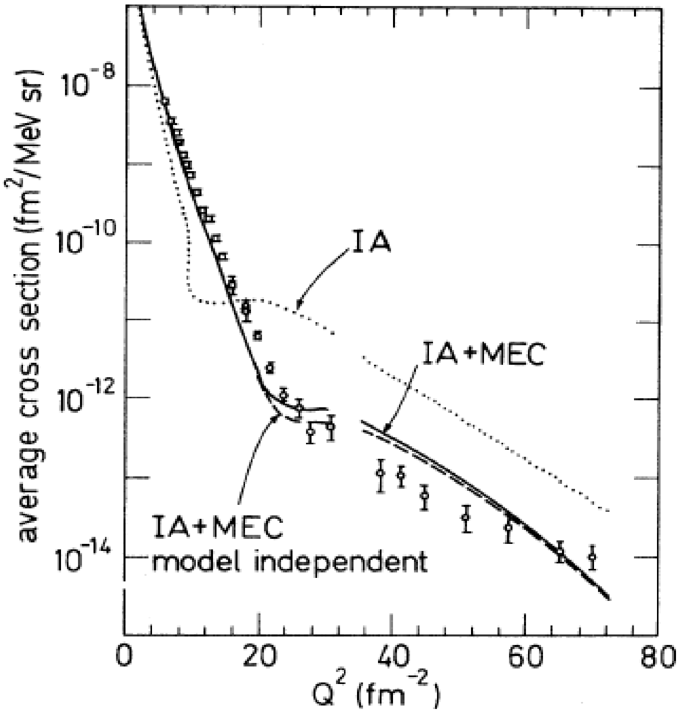


Fig. 8. Cross section for $E_{c.m.}$ = 3 MeV. The curve A shows the cross section when the pion and pair processes are taken into account and the curve B when also the Δ_{33} resonance contribution is included. The data points are the same as in fig. 4.

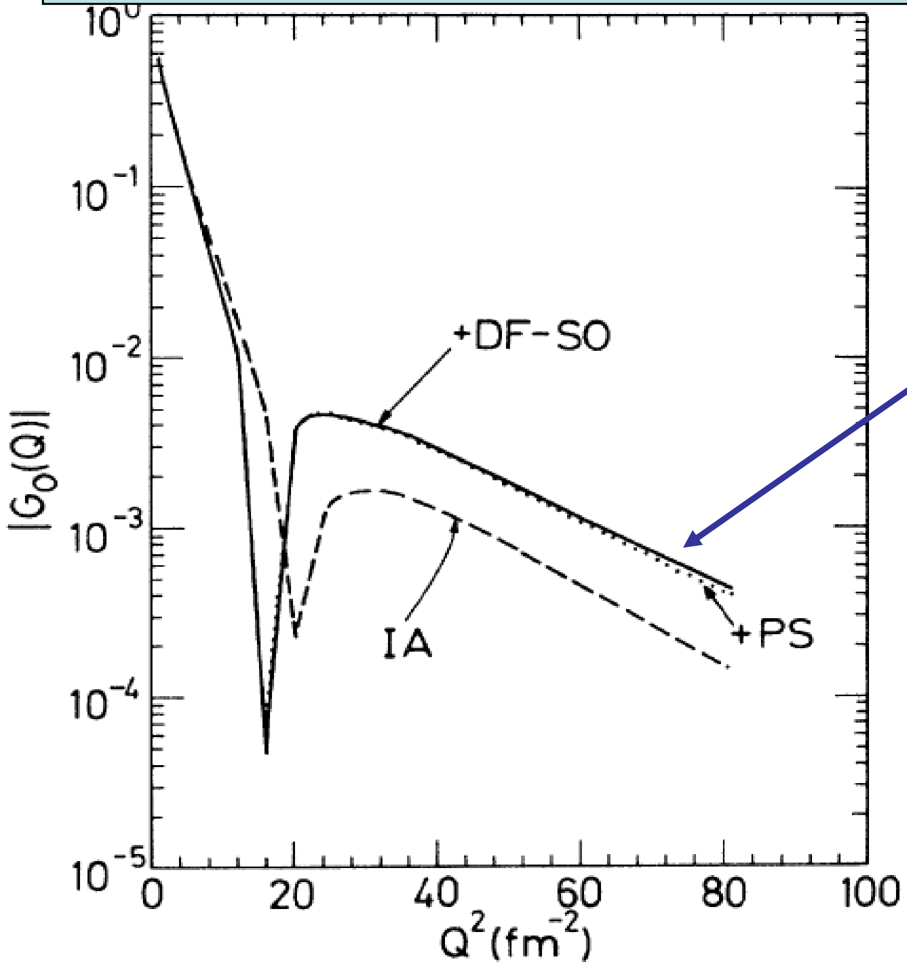


R. Schiavilla & DOR,
PR C43, 437 (1991)



π exchange dominance, because magnetic transition operator scales as $1/m_{ex}$, while interaction scales as m_{ex} !

DEUTERON CHARGE FORM FACTOR



+ exchange current

LO CHIRAL OPERATOR SUPPRESSED, YET PION EXCHANGE DOMINANCE ?

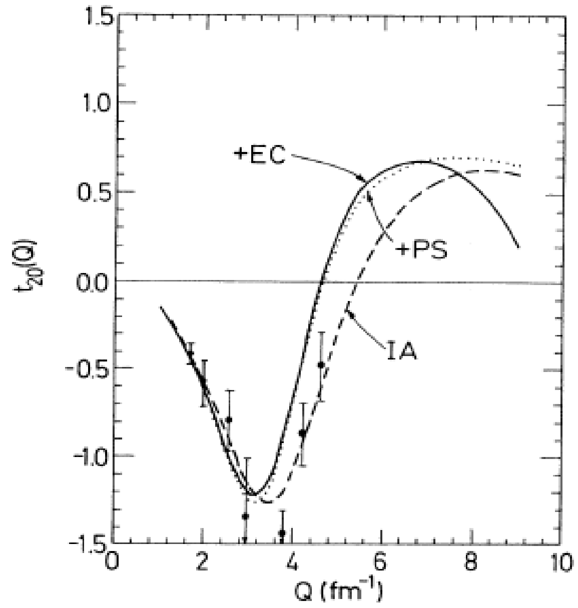
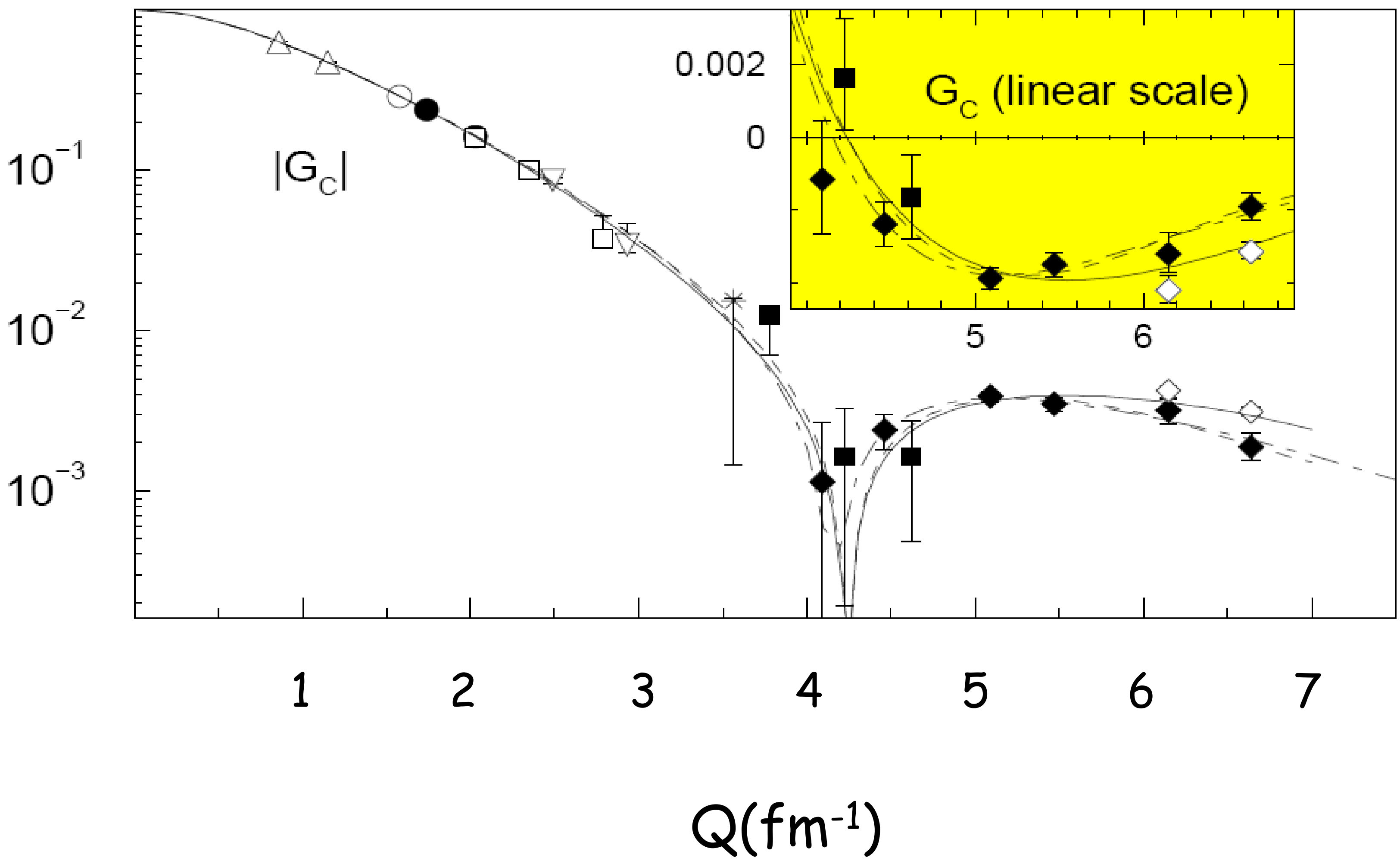


FIG. 21. The deuteron tensor polarization in the impulse approximation (IA) and with the inclusion of the exchange-charge and -current contributions, as well as the Darwin-Foldy and spin-orbit corrections (+EC). The results obtained when the contribution due to the PS ("generalized pion") exchange-charge operator is added to the impulse approximation are also shown (+PS). The Höhler *et al.*[9] parametrization of the nucleon electromagnetic form factors is used. The data points are from Refs. 34, 58, and 59.

R. Schiavilla & DOR, PR C43, 473 (1991)

JLAB t_{20} Collaboration, Eur Phys J A7, 421 (2000)



THE SKYRMION

THE SKYRMION

- SKYRME & PERRING 1969: 2-KINK SOL'N TO SINE-GORDON EQN:

  $S_1 \rightarrow S_1$ MAPPING
- SKYRME: HEDGEHOG ANSATZ FOR $S_3 \rightarrow S_3$
- NL SIGMA MODEL + STABILIZER
- WITTEN 1978: DYNAMICAL REALIZATION OF
- LARGE N QCD.
- BARYON PHENOMENOLOGY ~ QUARK MODEL

  $N=\infty$, $N=3$

Adkins, Nappi, Witten (1982)

CHIRAL HADRON DYNAMICS, QCD & THE SKYRMION

LARGE N : PLANAR DIAGRAMS, gluons ~ $q\bar{q}$ pair lines

π–hadron coupling: $\mathcal{L} = (1/f_\pi)\, A^\mu \cdot \partial_\mu \pi$

ROTATIONS

$A^{ia} = g\, N\, X^{ia}$; $X^{ia} = X_0^{ia} + (1/N)\, X_1^{ia} + \ldots$

Relation to Skyrme model: $X_o^{ia} = (1/2)\, \mathrm{Tr}\{ A\sigma^i A^\dagger \tau^a \}$

SU(4) generators:

$J^i = (1/2)\sum_k^N q_k^\dagger \sigma^i q_k$; $I^a = (1/2) \sum_k^N q_k^\dagger \tau^a q_k$;

$G^{ia} = (1/4)\sum_k^N q_k^\dagger \sigma^i \tau^a q_k$

SKYRME MODEL & NUCLEON SPECTRUM

LOW LYING VIBRATIONAL STATE:

$E(1/2^*) - E(1/2) = 400$ MeV,   expt: 500 MeV

L.C.Biedenharn et al, PRD 31, 649 (1985)

I=J states OK,

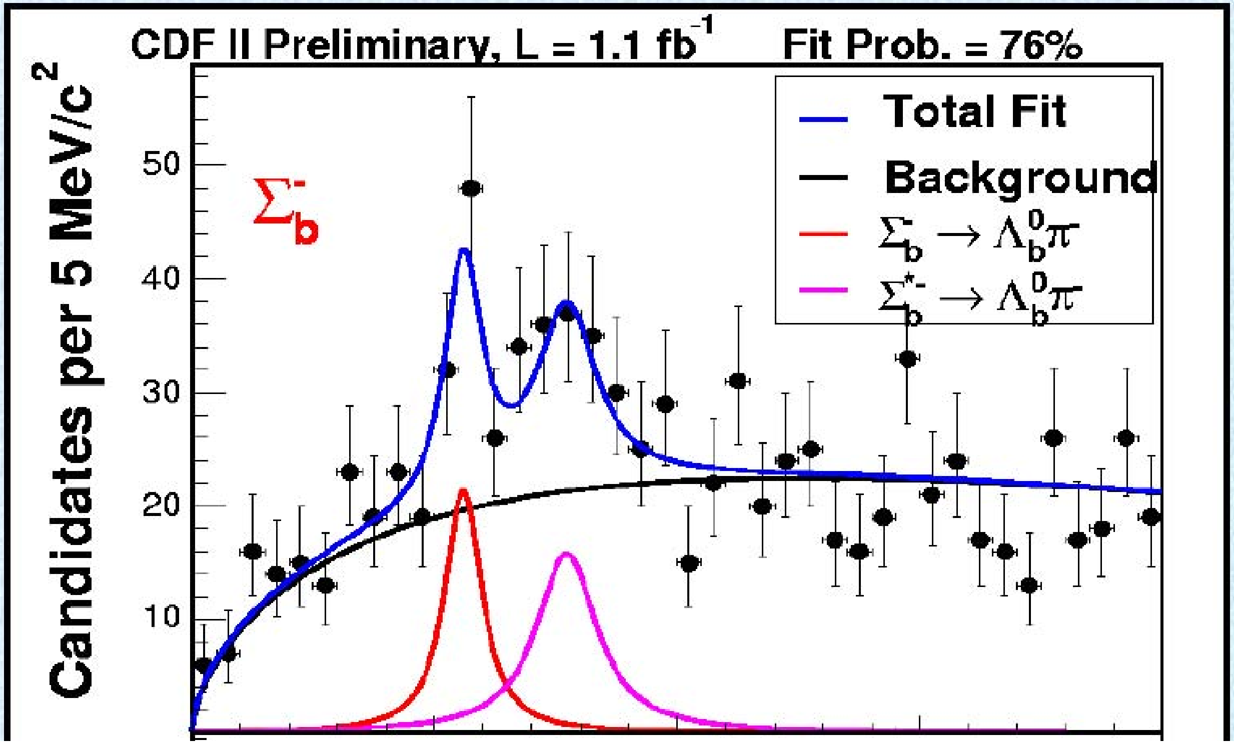
L.C.Mattis & M. Karliner, PRD 31, 2833 (1985)

HYPERONS IN THE SKYRME MODEL

- STRANGE, CHARM, BEAUTY MESONS BOUND IN THE SOLITON FIELD
- QUANTUM NUMBER TRANSFORMATION:
- ISOSPIN ½ -> SPIN ½ K,D,B MESONS
- C. Callan & I. Klebanov, Nucl Phys B262,365 (1984),
- N. Scoccola et al realization
- INCORPORATES HEAVY QUARK SYMMETRY

FERMI LAB PRESS RELEASE OCT '06

- $m(\Sigma_b^{+}) = 5808^{+2.0}_{-2.3}$(stat.) $\pm$ 1.7(syst.) MeV/c^2
- $m(\Sigma_b^{-}) = 5816^{+1.0}_{-1.0}$(stat.) $\pm$ 1.7(syst.) MeV/c^2
- $m(\Sigma_b^{*+}) = 5829^{+1.6}_{-1.8}$(stat.) $\pm$ 1.7(syst.) MeV/c^2
- $m(\Sigma_b^{*-}) = 5837^{+2.1}_{-1.9}$(stat.) $\pm$ 1.7(syst.) MeV/c^2



Skyrme: $m(\Sigma_b)$ = 5806 MeV, $m(\Sigma_b^*)$= 5826 MeV

M. Rho, N.Scoccola & DOR, Z.Phys.A, 341 (1992)

DOUBLE CHARM HYPERONS

M. Rho et al, Z Phys A341 343 (1992)

$\Xi_{cc}^{+}(3520)$

SELEX, PLB 628 (2005) 18

$\Xi_{cc}^{++} \sim 3460$

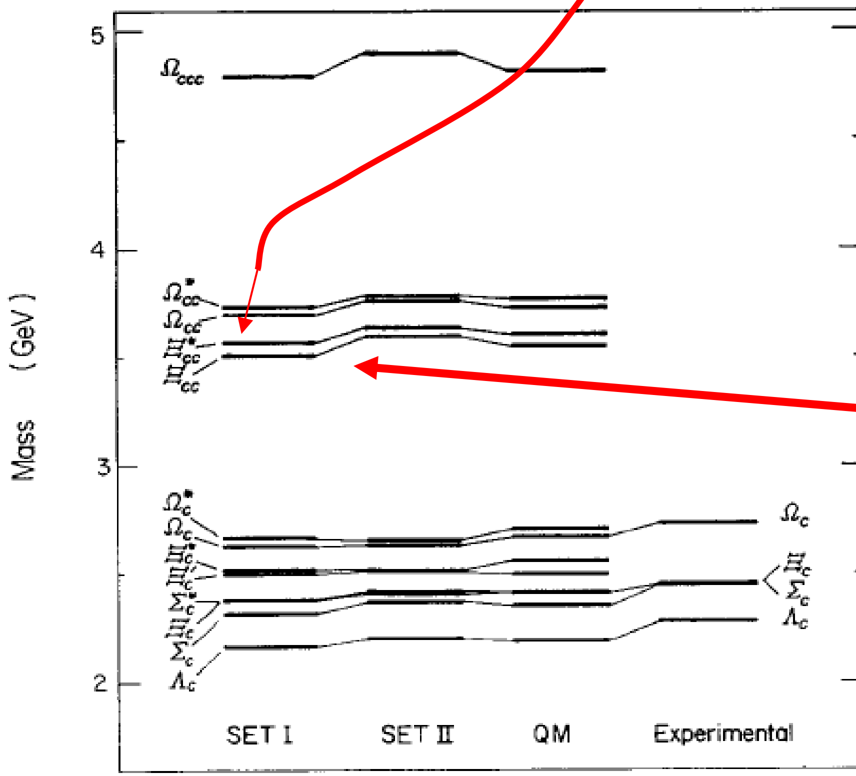
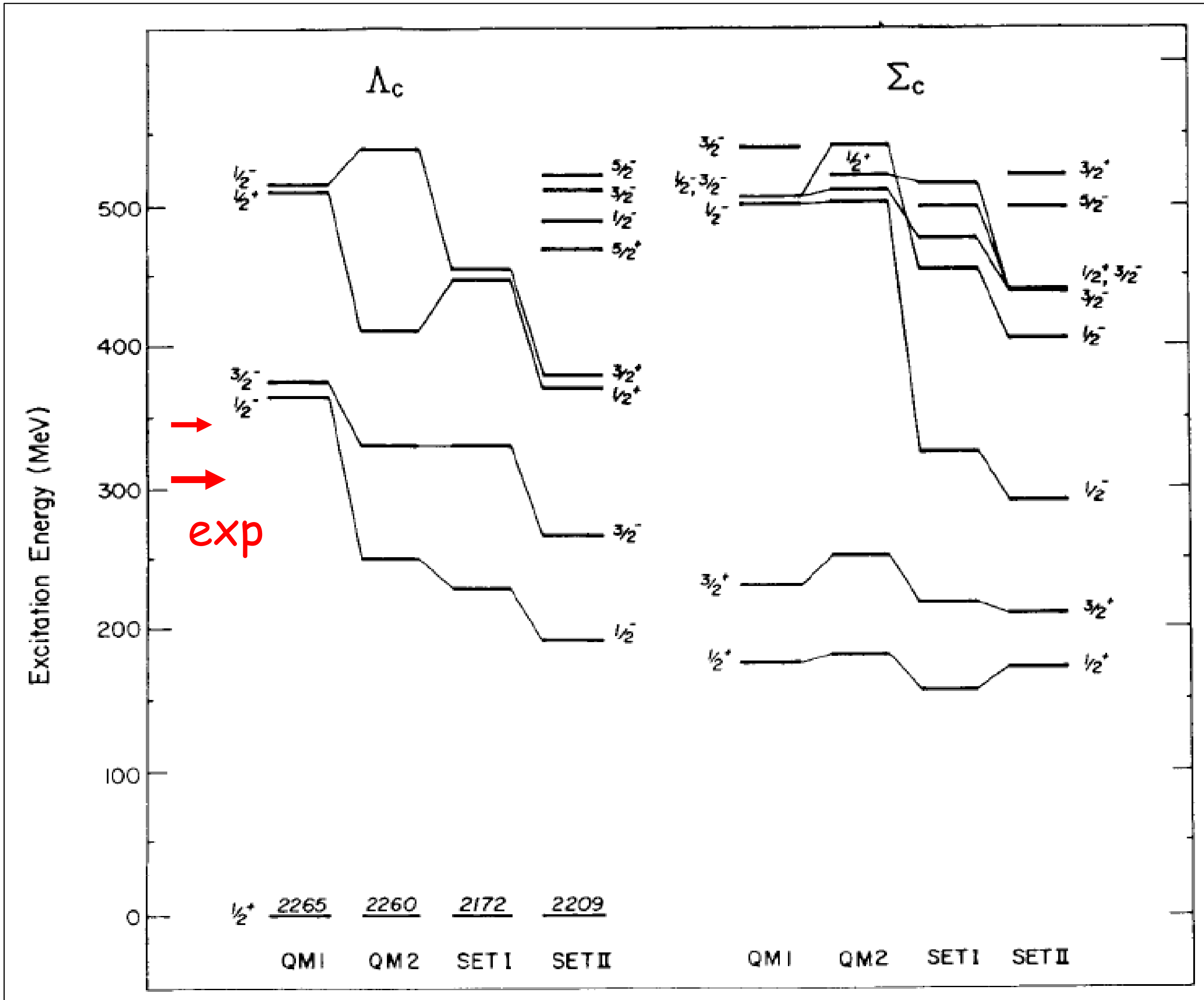


Fig. 1. The energies of the stable charmed and strange-charmed hyperons. The results denoted SET I are those obtained with zero pion mass, and those denoted SET II those obtained with $m_\pi = 138$ MeV. For comparison the quark model results (QM) of [29] are also shown

SKYRME MODEL ~ QUARK MODEL FOR GROUND STATE BARYONS



Λc
Σc
Excitation Energy (MeV)
exp
QM1
QM2
SET I
SET II
2265
2260
2172
2209

NUCLEI AS SKYRMIONS

Nucleons: $U(\mathbf{r}) = \exp\{i\, F(r)\, \pi\cdot\mathbf{r}\}$; F(r): soln to 2nd order diff. eqn

Nuclei: B=2 ground state solution has axial symmetry

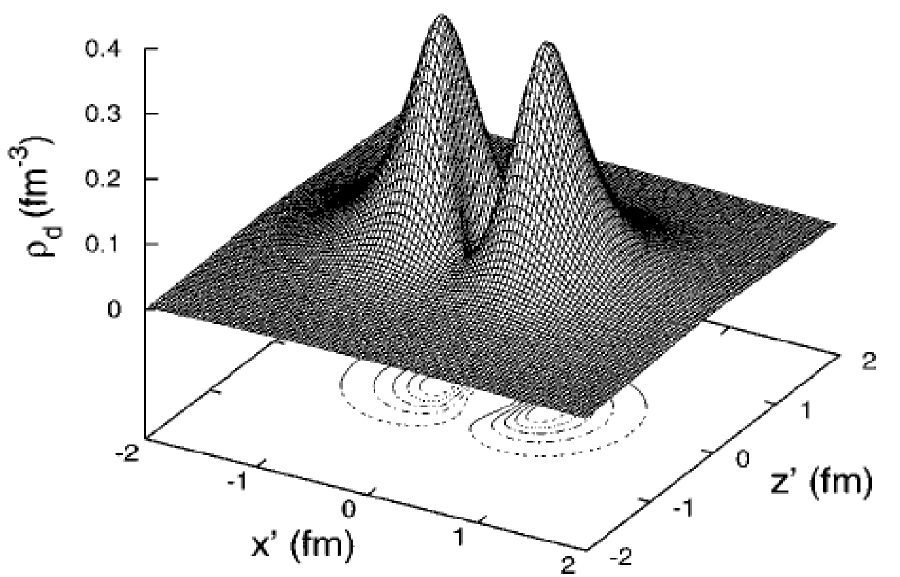
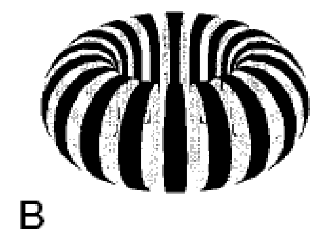


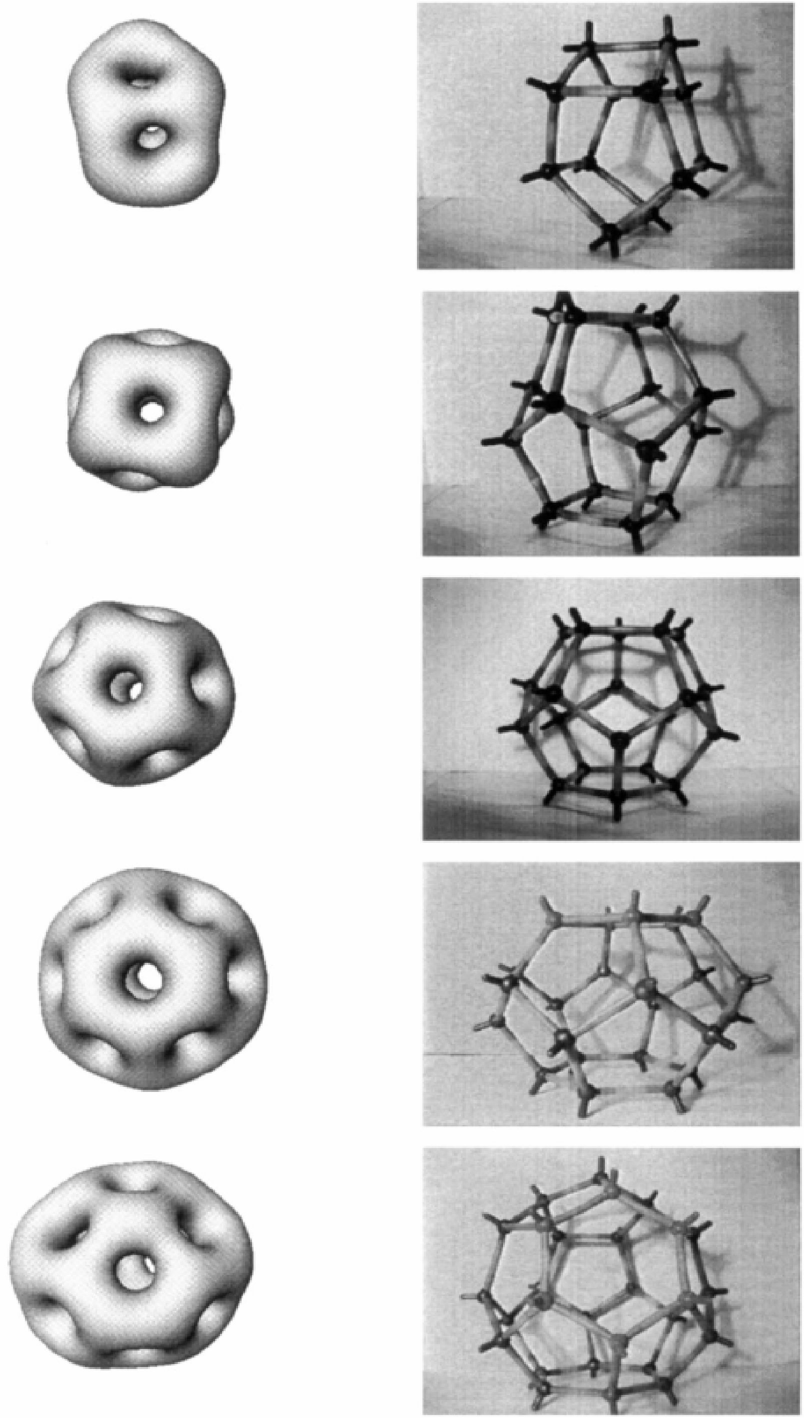
FIG. 4. The deuteron density $\rho_d^0(x', z')$ obtained from the Argonne v_{18} model. The peaks are located at $z'=0$ and $x'=\pm d/2$.



$M_d=0$

$\rho_d^0(\mathbf{r}')=0.24\ \mathrm{fm}^{-3}$ (B)

J.L.Forest et al,
PRC 54, 646 (1996)



R. A. Battye & P. M. Sutcliffe,
PRL 79, 363 (1997)

FIG. 1. Skyrmions of charge 5 to 9; on the left baryon density isosurfaces (to scale) with 5 at the top and 9 at the bottom and on the right wire frame models of the corresponding solids. Note that the wire frame models are not to scale and have different orientations to the baryon density plots.

SKYRME'S PRODUCT ANSATZ

$U(r;r_1,r_2) = U(r-r_1\ )\ U(r-r_2)$

$L = L_1 + L_2 + L_{int}$ $\pi\pi$ exchange interaction, realistic
isospin dependent interaction components

Current density:

$j = j_1 + j_2 + j_{int}$

Deuteron magnetic form factor

E M Nyman & DOR, PRL 24, 3007 (1986)

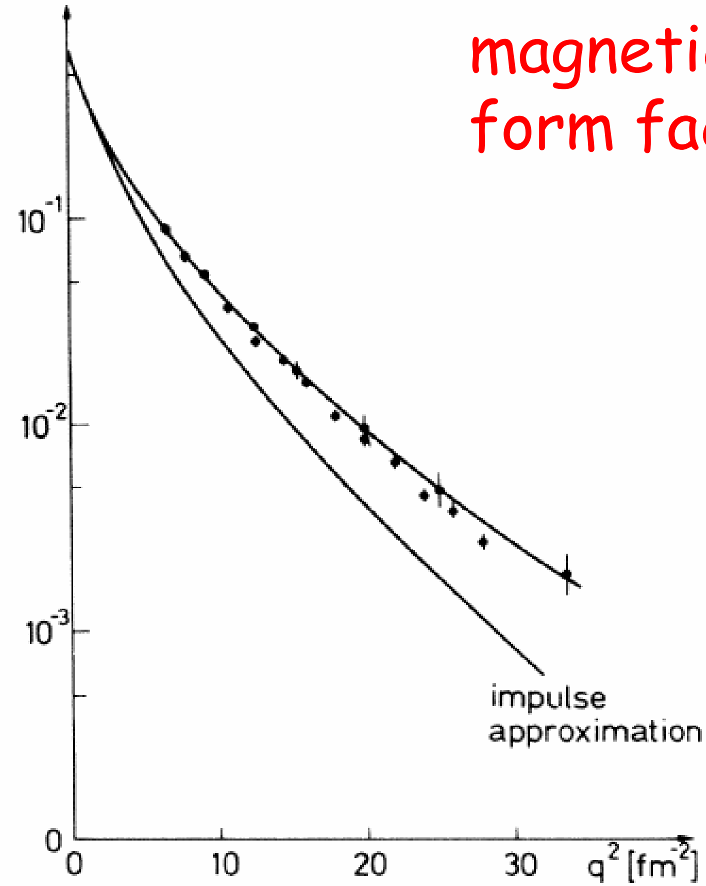
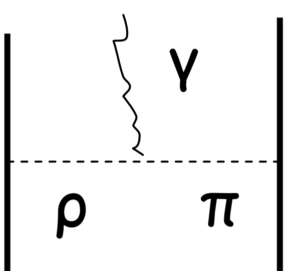
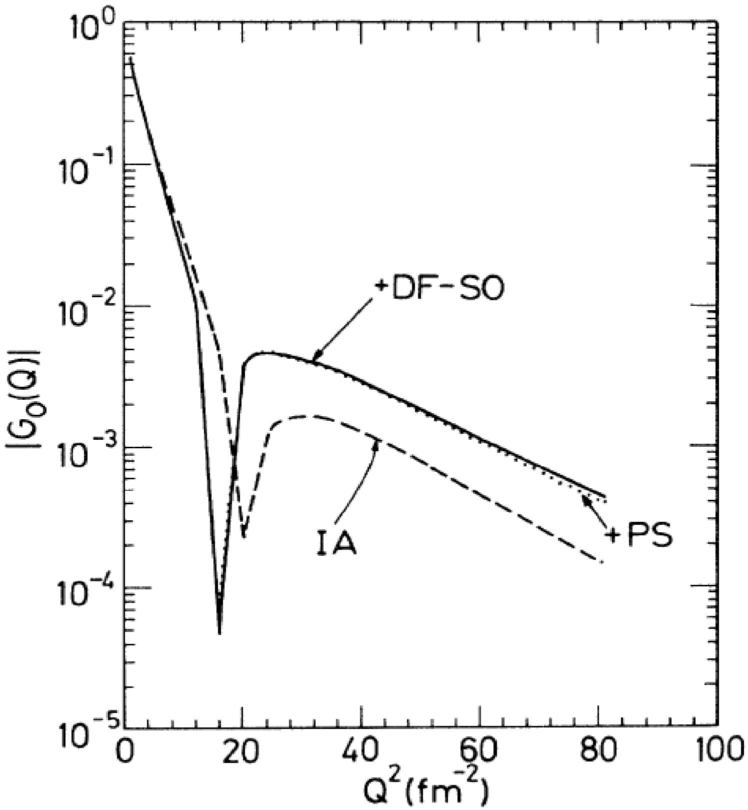


FIG. 2. Magnetic form factor of the deuteron vs momentum transfer. Shown is the contribution from the complete topological current well as that of the impulse approximation, where the exchange current contribution is neglected. The chiral angle has been determined from the isoscalar electric form factor of the single nucleon.

Exchange current Identical in form to ρ-π-γ current, M. Wakamatsu, W. Weise, NPA 477, 559 (1988)





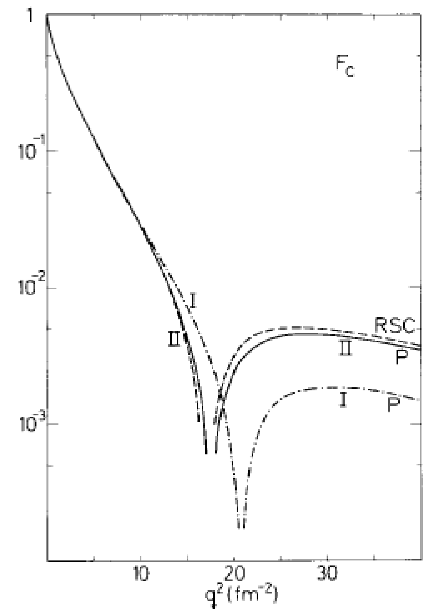


Fig. 5. The charge form factor of the deuteron using the chiral angle given by the dipole form for G_E^S. The curves I and II are the impulse approximation and complete results as obtained with the Paris-potential deuteron wavefunctions. The curve RSC is the result obtained with the Reid soft-core potential wavefunctions.

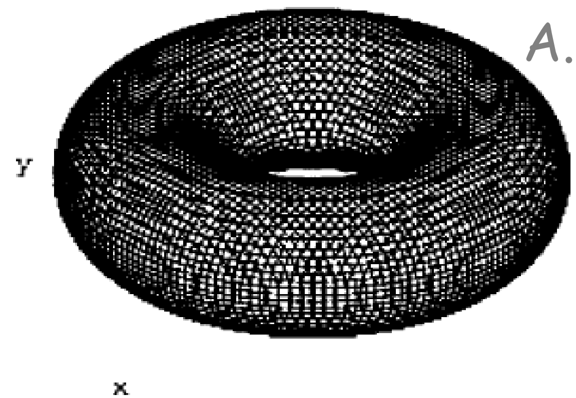
NUCLEAR WAVE FUNCTION
&
EXCHANGE CURRENTS

~

PRODUCT ANSATZ
SKYRME MODEL

Ground state solution with quantized rotational degrees of freedom

A. Acus et al, Phys. Scripta 69, 260 (2004)



Equidensit

Product ansatz, EM Nyman, DOR 1987

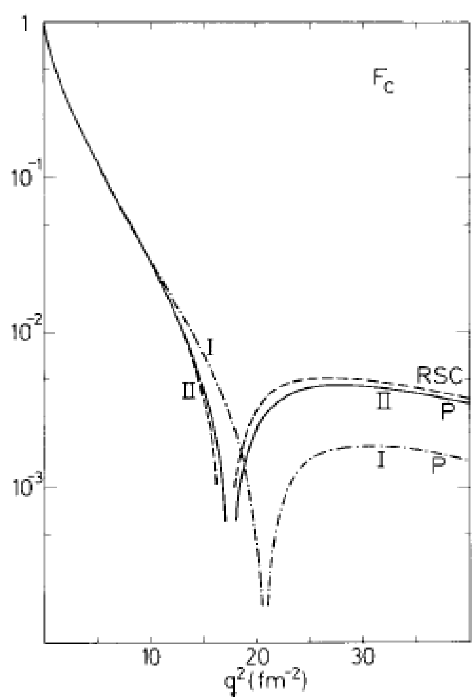


Fig. 5. The charge form factor of the deuteron using the chiral angle given by the dipole form for G_E^S. The curves I and II are the impulse approximation and complete results as obtained with the Paris-potential deuteron wavefunctions. The curve RSC is the result obtained with the Reid soft-core potential wavefunctions.

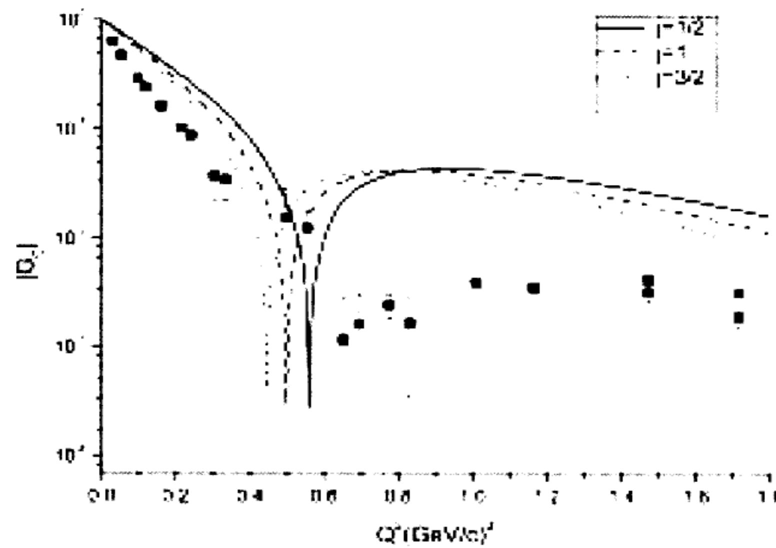
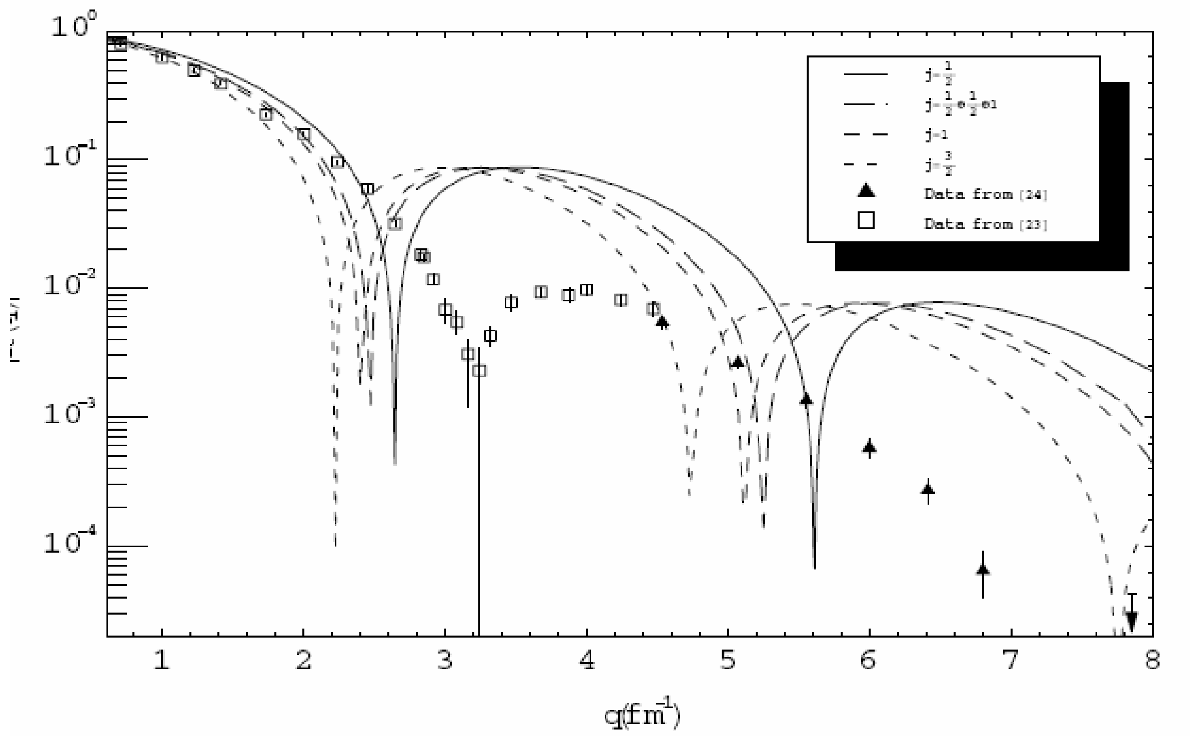


Fig. 3. Electric form factor of the quantized deuteron solution. The experimental data are from [16].



PRODUCT ANSATZ OVERSHOOTS!

A. Acus* and E. Norvaišas
D. O. Riska

PHYSICAL REVIEW C **74**, 025203 (2006)

FIG. 2. Comparison of ^4He electric form factors in different representations of SU(2) with experimental data [23,24]. The form factors are calculated with parameters that yield the experimental nucleon mass $m_N = 939$ MeV and radius $r = 0.72$ fm [11].

POINCARÉ INVARIANCE

WHY DOES PHOTONUCLEAR THEORY WORK ?

- ALMOST ALL PHOTO & ELECTRONUCLEAR FORMALISM EMPLOYS GALILEAN COVARIANT Q.M. WITH MINOR MODIFICATIONS DUE TO DIRAC SPINORS
- WHY ARE Q^2/M^2 EXPANSIONS NOT MISLEADING ?
- WHY DOESN'T THE QUARK MODEL PROVIDE A REALISTIC DESCRIPTION OF BARYON RESONANCE DECAYS?

GENERATORS OF POINCARÉ TRANSFORMATIONS

10 GENERATORS H, P_i, J_i, K_i

6 KINEMATIC GENERATORS, 4 SPECIFIED BY DYNAMICS THROUGH POINCARÉ ALGEBRA

3 ALTERNATIVES:

-INSTANT KINEMATICS P,J KINEMATIC O(3), E(3)*
-POINT KINEMATICS J, K KINEMATIC SO(1,3)
-FRONT KINEMATICS P, K KINEMATIC O(1,2)

* CONVENTIONAL, FIXED t HYPERPLANE

HAMILTONIAN: GALILEAN INVARIANCE ~ POINCARÉ INVARIANCE (LITTLE GROUP OF G AND P TRANSFORMATIONS COINCIDE)

CURRENTS: IN, OUT FRAME DIFFERENT: BOOSTS MATTER

EXAMPLE: FORM FACTORS
IN REST FRAME, BREIT FRAME $\sum p_i = \pm Q/2$

THE ROLE OF BOOSTS

INSTANT FORM:

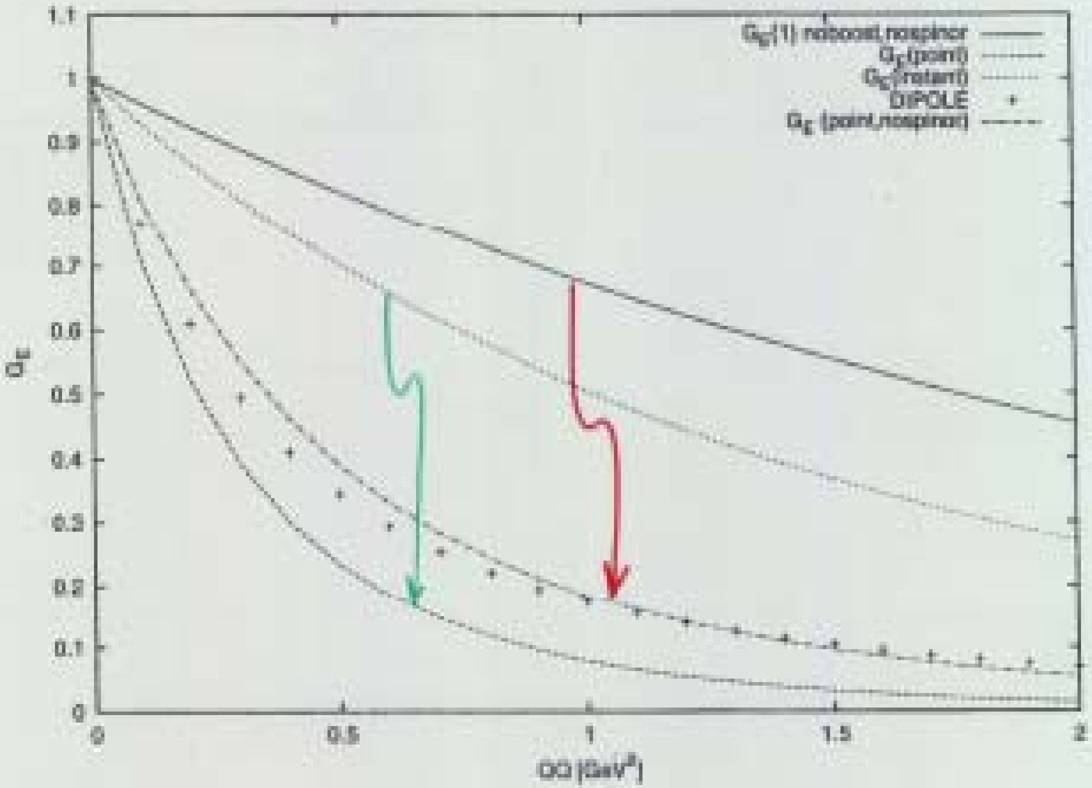
$v = \pm\, p/\sum \omega_i$ $\quad$ $v \sim Q^0$ boosts remain small

POINT FORM:

$v = \pm\, p/M$ $\quad$ $v \sim Q^1$ boosts grow with Q

FRONT FORM:

Lightfront kinematics, boost invariant; spin dynamical



NUCLEON FORMFACTOR
DUE TO KINEMATICS!

IN POINT FORM THE NUCLEON FORM FACTOR ARISES FROM THE BOOST!

CHOICE OF KINEMATICS A MATTER OF PHENOMENOLOGICAL CONVENIENCE

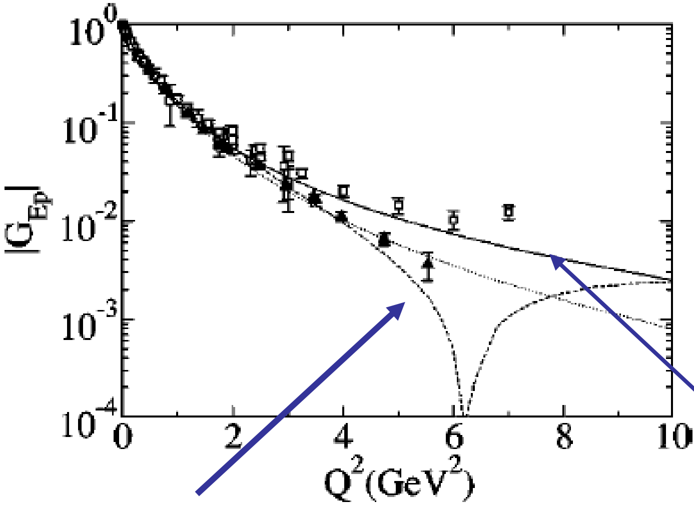
NUCLEON FORM FACTORS IN THE QUARK MODEL IN 3 FORMS OF KINEMATICS, B.JULIA-DIAZ et al, PRC C69, 035212(2004)

SU(6) SPIN-ISOSPIN WAVEFUNCTION $\times$ $\varphi(P)$;

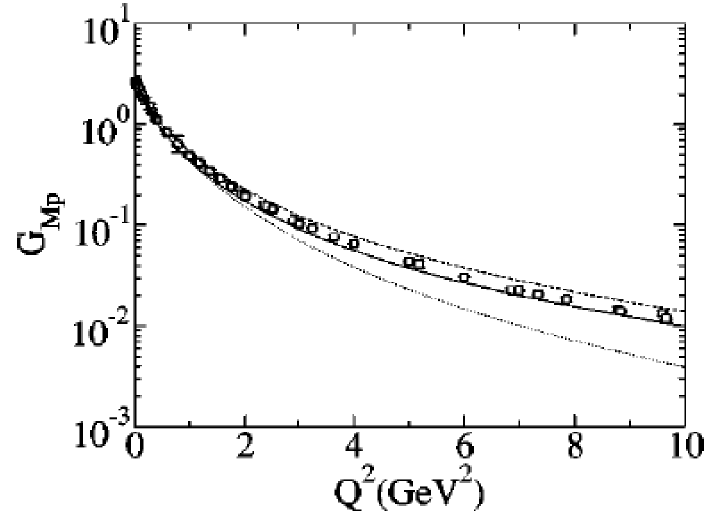
P = hypersperical momentum

$\varphi(P) \sim (1+P^2/4\,b^2)^{-a}$

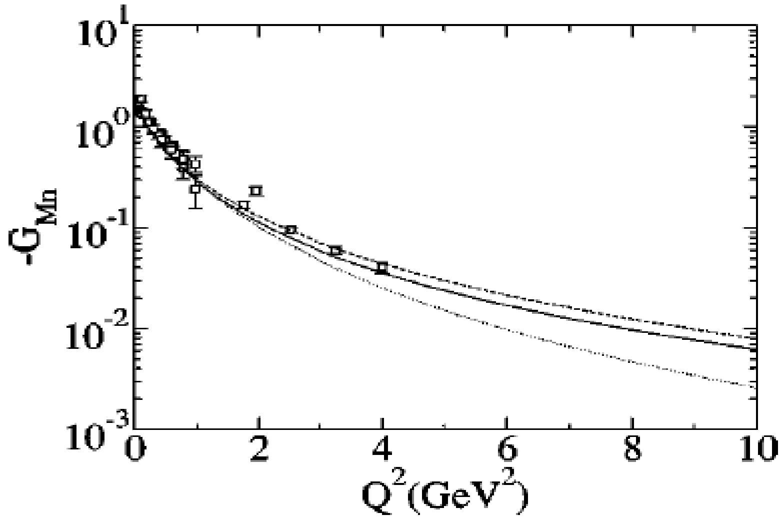
	a	b (MeV)	matter radius (fm)
INSTANT	6	600	0.63
POINT	2.25	640	0.19
FRONT	4	500	0.55



FRONT

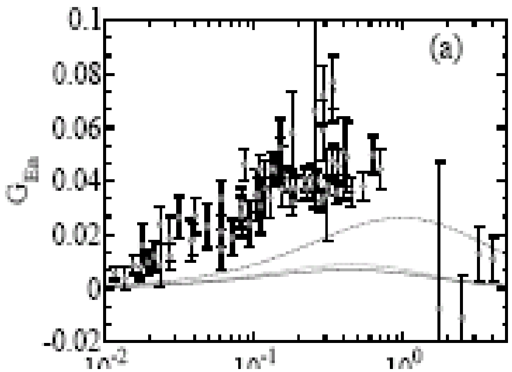


INSTANT

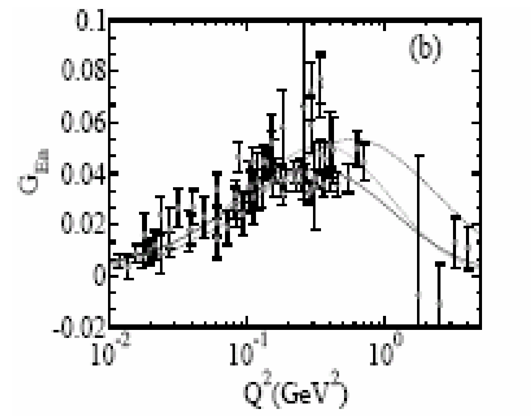


IF G_E HAS A NODE, FRONT FORM MAY BE OPTIMAL

$G_E(n)$



solid: instant, dotted: point
dashed: front

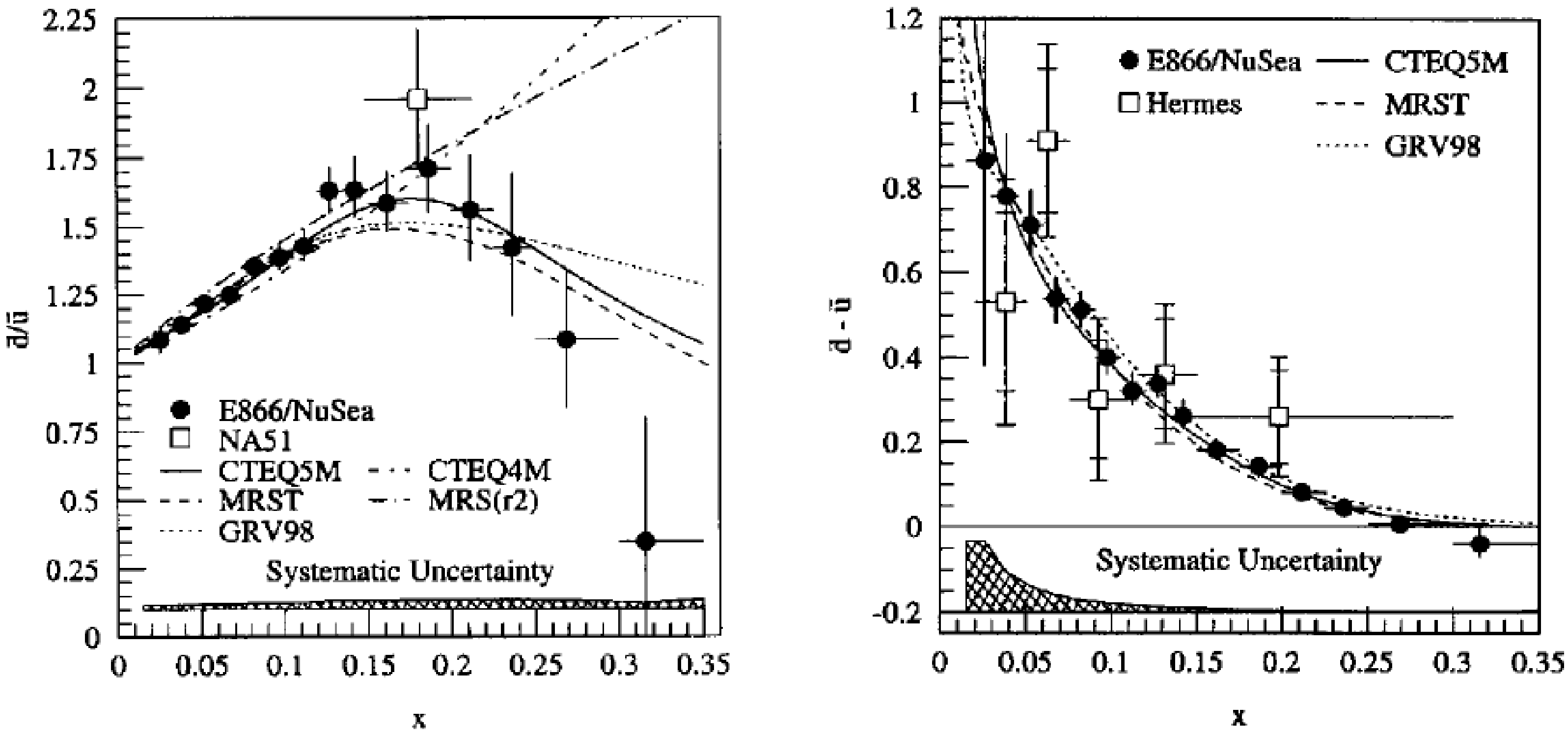


S′: 2% instant,point,
1% front

Consistent quark model demands covariant
treatment of the boosts

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

FLAVOR ASYMMETRY IN THE PROTON

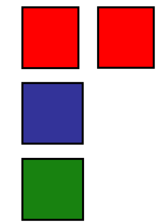


G.Garvey and J.C.Peng, Prog.Part.Nucl.Phys. 47, 203 (2001)

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

$qqqq\bar{q}$ CONFIGURATIONS

qqqq SUBSYSTEM TOTALLY ANTISYMMETRIC



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

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

EITHER:

a) SPACE: SYMMETRIC [4], SPIN-FLAVOR: [31]

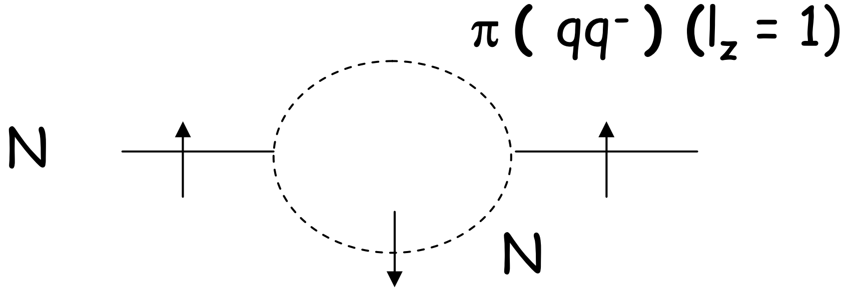
OR

b) SPACE: MIXED SYM: [31], SPIN-FLAVOR: [4]

1. SYMMETRIC SPATIAL WAVE FUNCTION: [4]

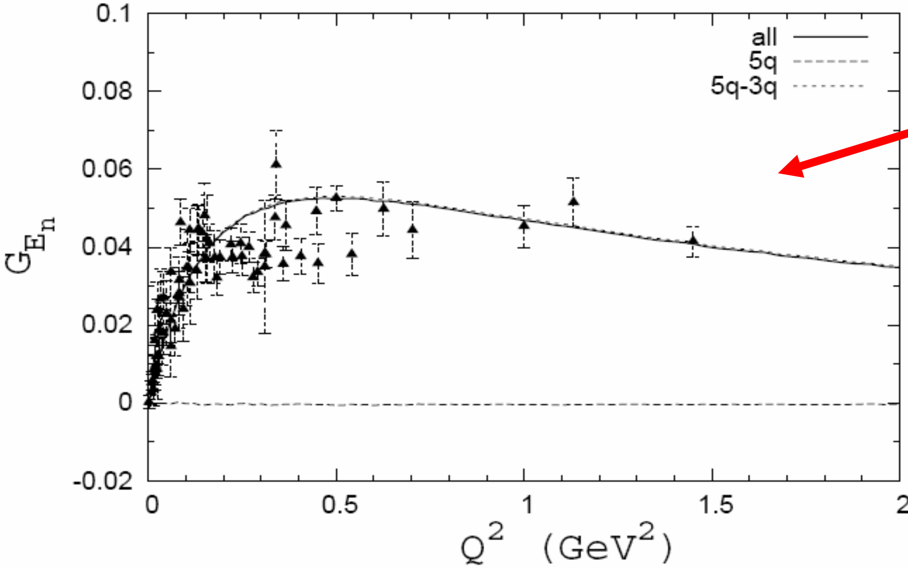
qqqq IN S-STATE, q^- IN P-STATE (q^- : - PARITY)

CORRESPONDS TO π – N OR K-HYPERON LOOP

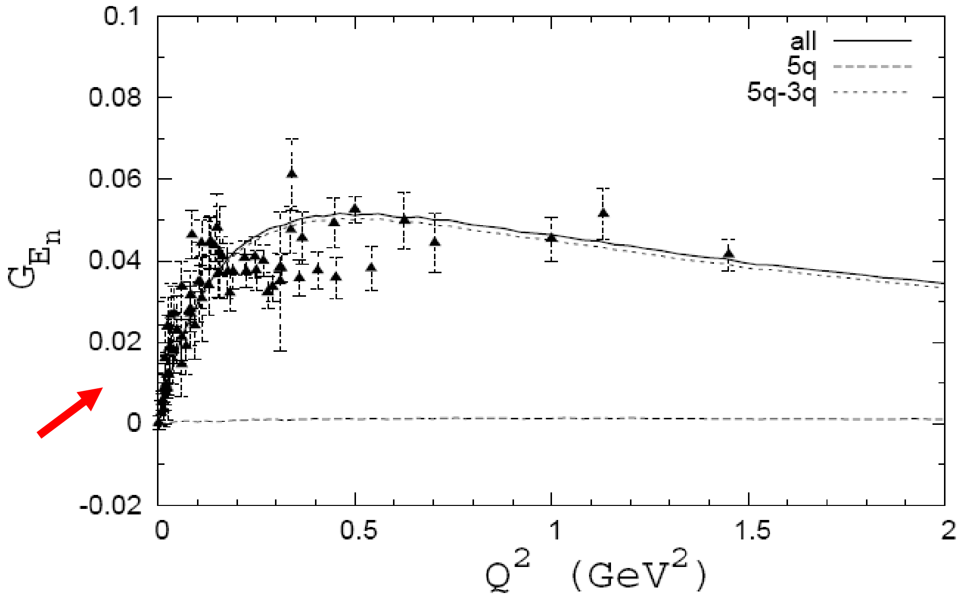


2. MIXED SYMMETRY SPATIAL WAVE FUNCTION: [31]

ONE QUARK IN P-STATE, q^- IN S-STATE

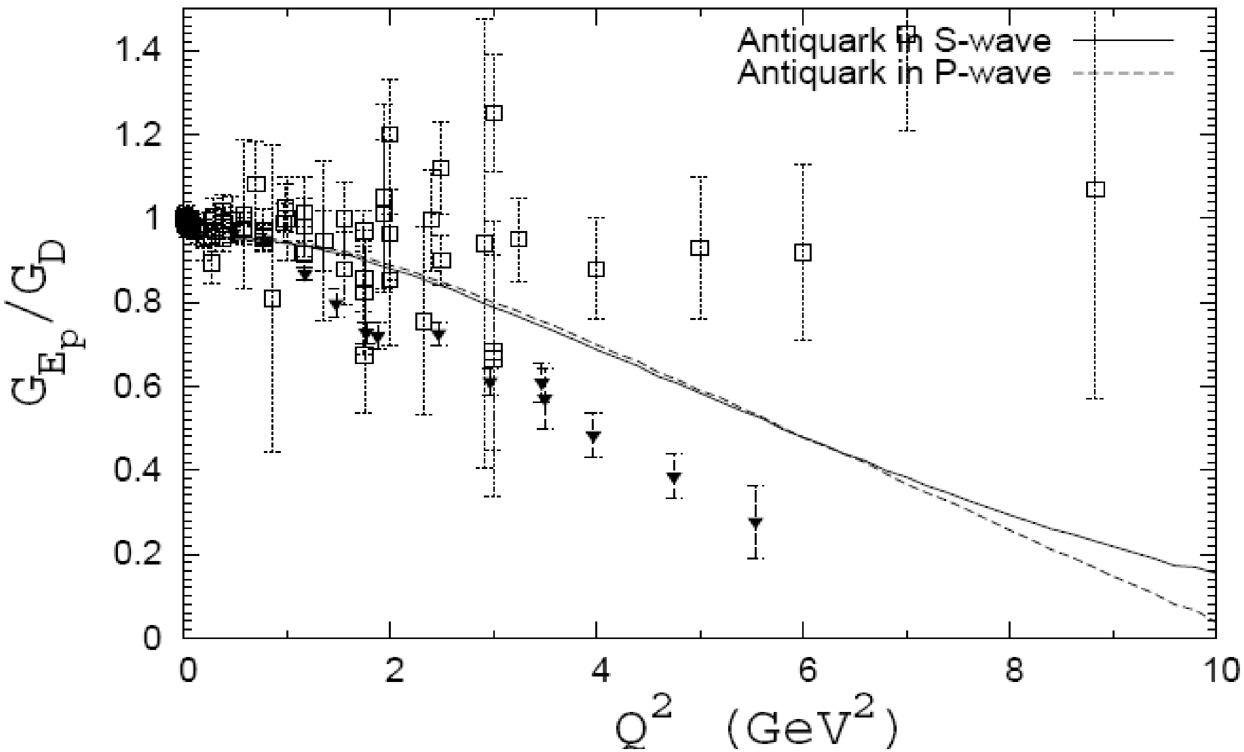


Antiquark in S-state
3% qqqq$\bar{q}$

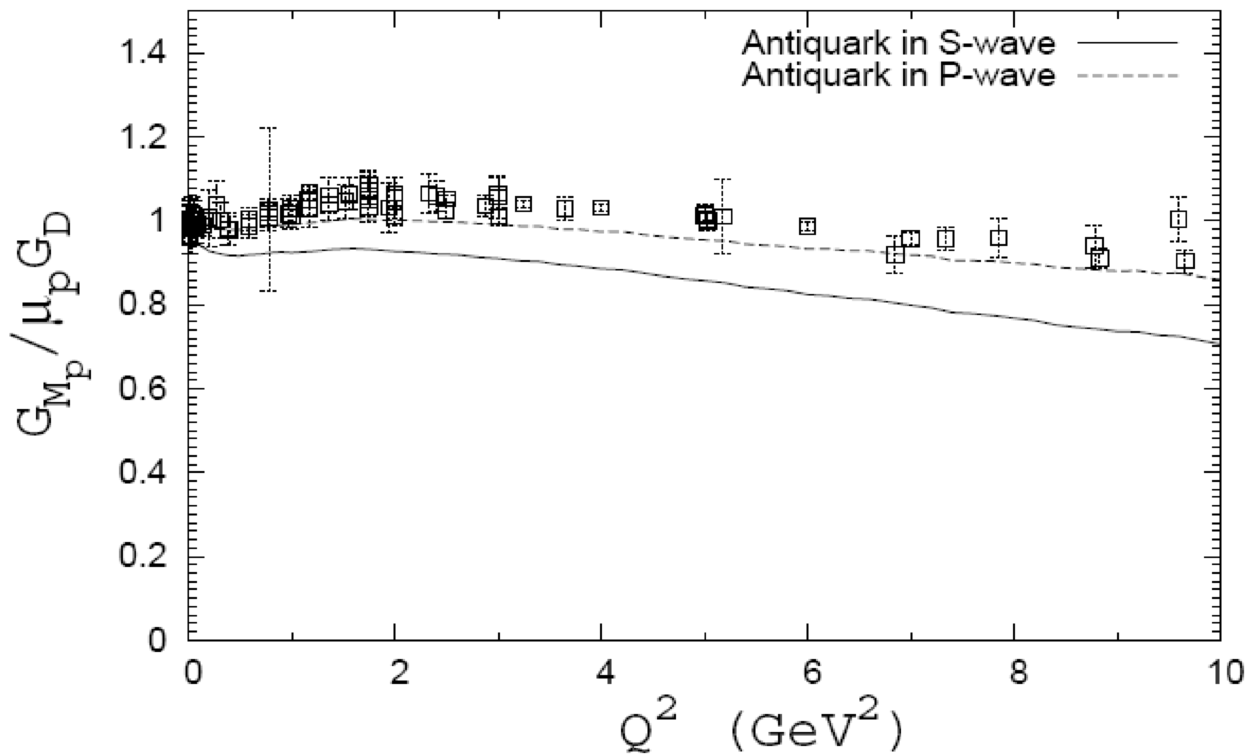


Antiquark in P-state
3% qqqq$\bar{q}$

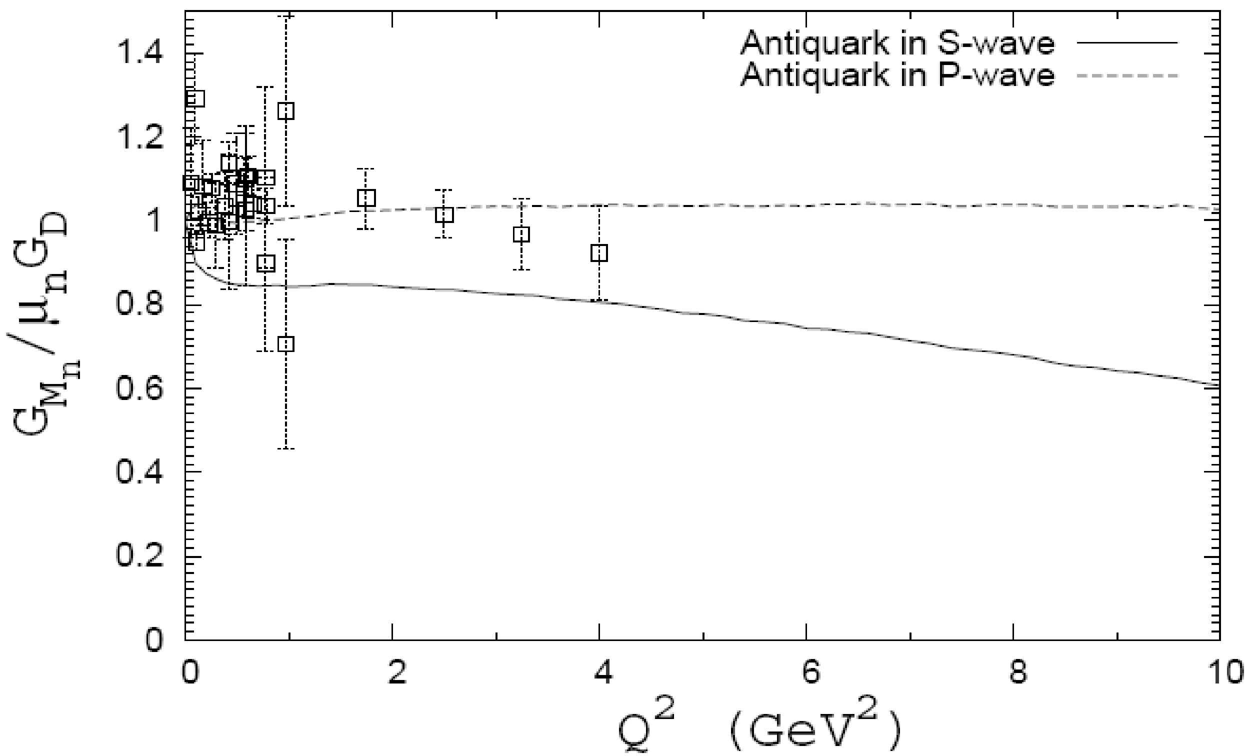
Qiang-Bing Li & DOR, nucl-th/0702049



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



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


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

SUMMARY

- NUCLEAR OBSERVABLES ARE OFTEN MOST SENSITIVE TO LONG RANGE CHIRAL DYNAMICS
- THE SKYRMION LINKS LO CHIRAL DYNAMICS TO LARGE N QCD
- CHOICE OF POINCARÉ COVARIANT QUANTUM MECHANICS A MATTER OF CONVENIENCE
- UNQUENCHING OF THE QUARK MODEL SOLVE MANY PROBLEMS IN Q.M. PHENOMENOLOGY