SPIN 08

Symmetry and Supersymmtry in Basic Nuclear Force. Dibaryon Concept for NN Interactions.

V.I. Kukulin and V.N. Pomerantsev

Skobeltsyn Institute of Nuclear Physics,

Moscow State University

Content

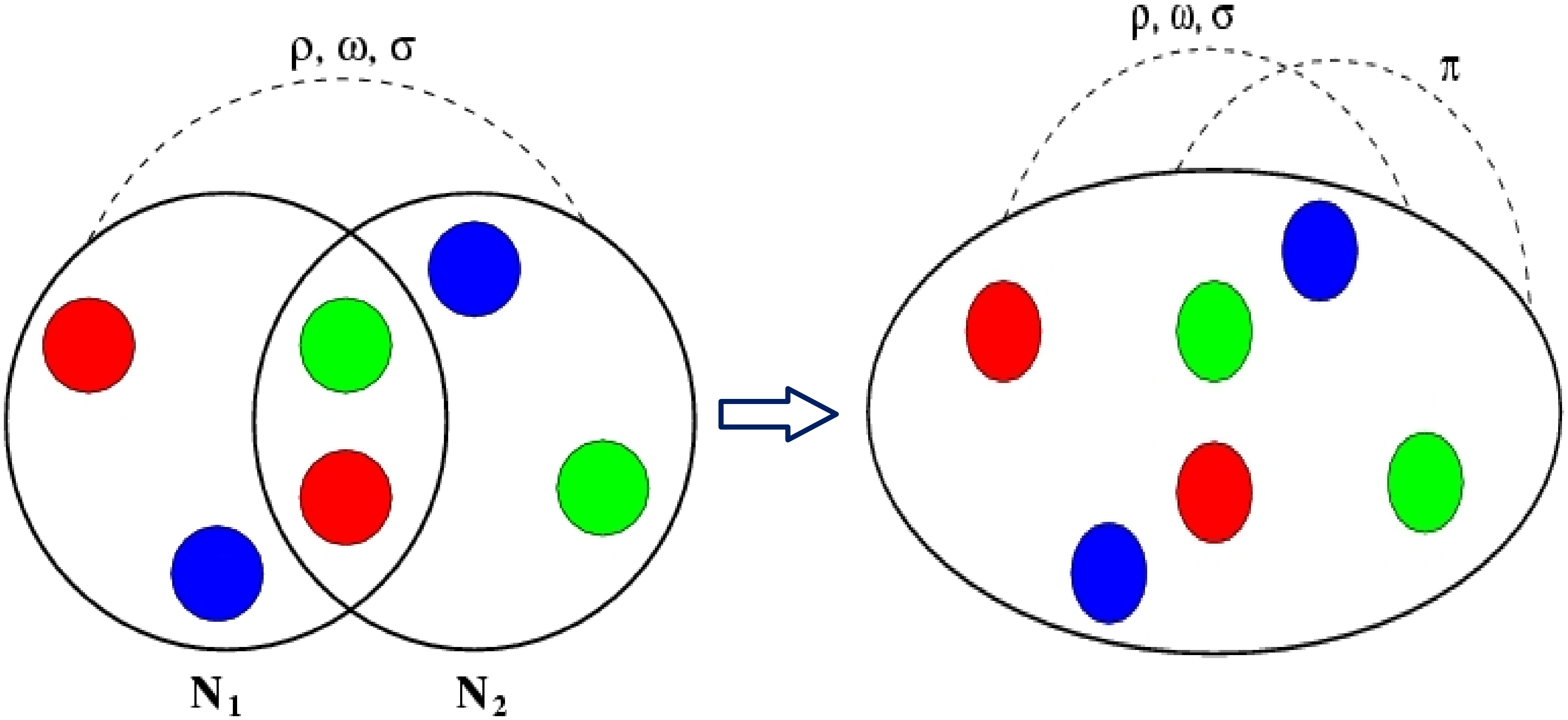
1. Quark model description for short-range NN interaction: symmetry in NN-force.

   Where is basic NN attraction?

2. NN potential models describing NN quark-model wavefunctions and phase shits (the Moscow NN potential).
3. Supersymmetrical quantum mechanics and supersymmetry in NN interaction.
4. Dibaryon concept for nuclear force and ABC puzzle.
5. Roper-resonanse structure and σ-field in Roper.
6. Hybrid nature for σ-meson and dressed dibaryon.
7. Experimental evidences for the dibaryon concept.
8. Summary.

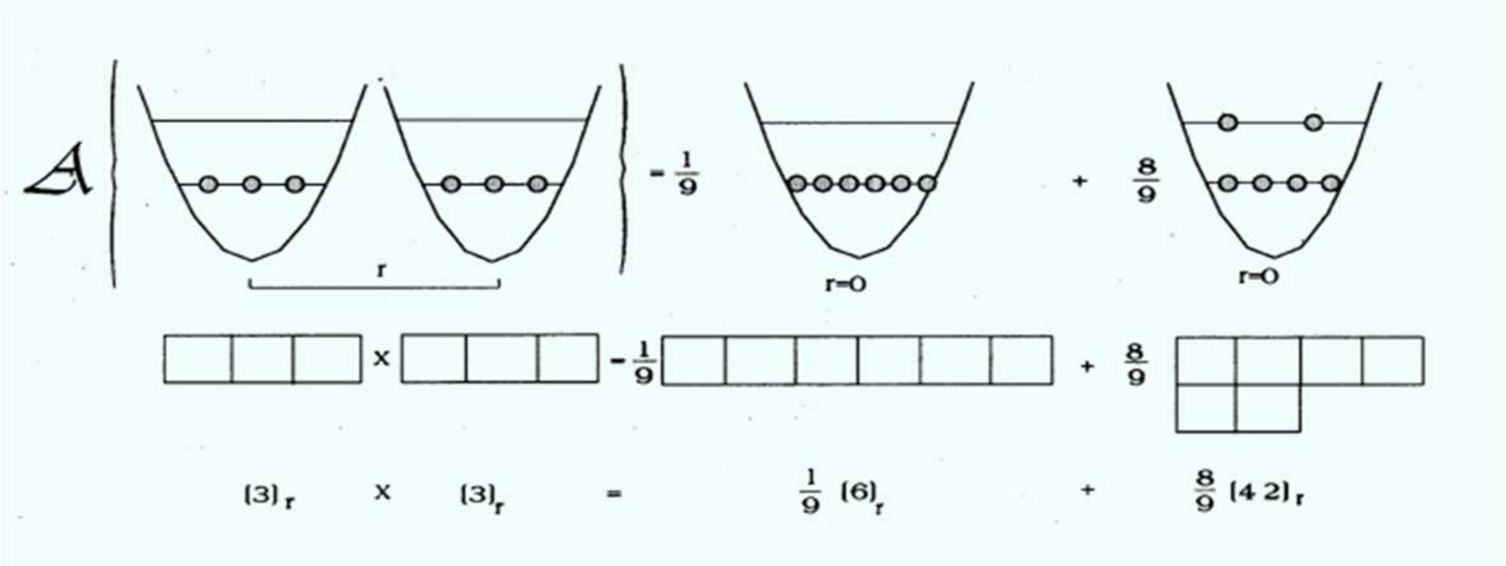
Short- and intermediate-range nuclear force

- At r_{NN}>1.2-1.4 fm the NN interaction is mediated by □ and 2□ - exchange (i.e. Yukawa picture). However when r_{NN} < 1.2 fm (i.e. at intermediate and short ranges) two nucleons overlapped and the whole picture of interaction is dictated by quark dynamics.



Short- and intermediate-range nuclear force in quark models

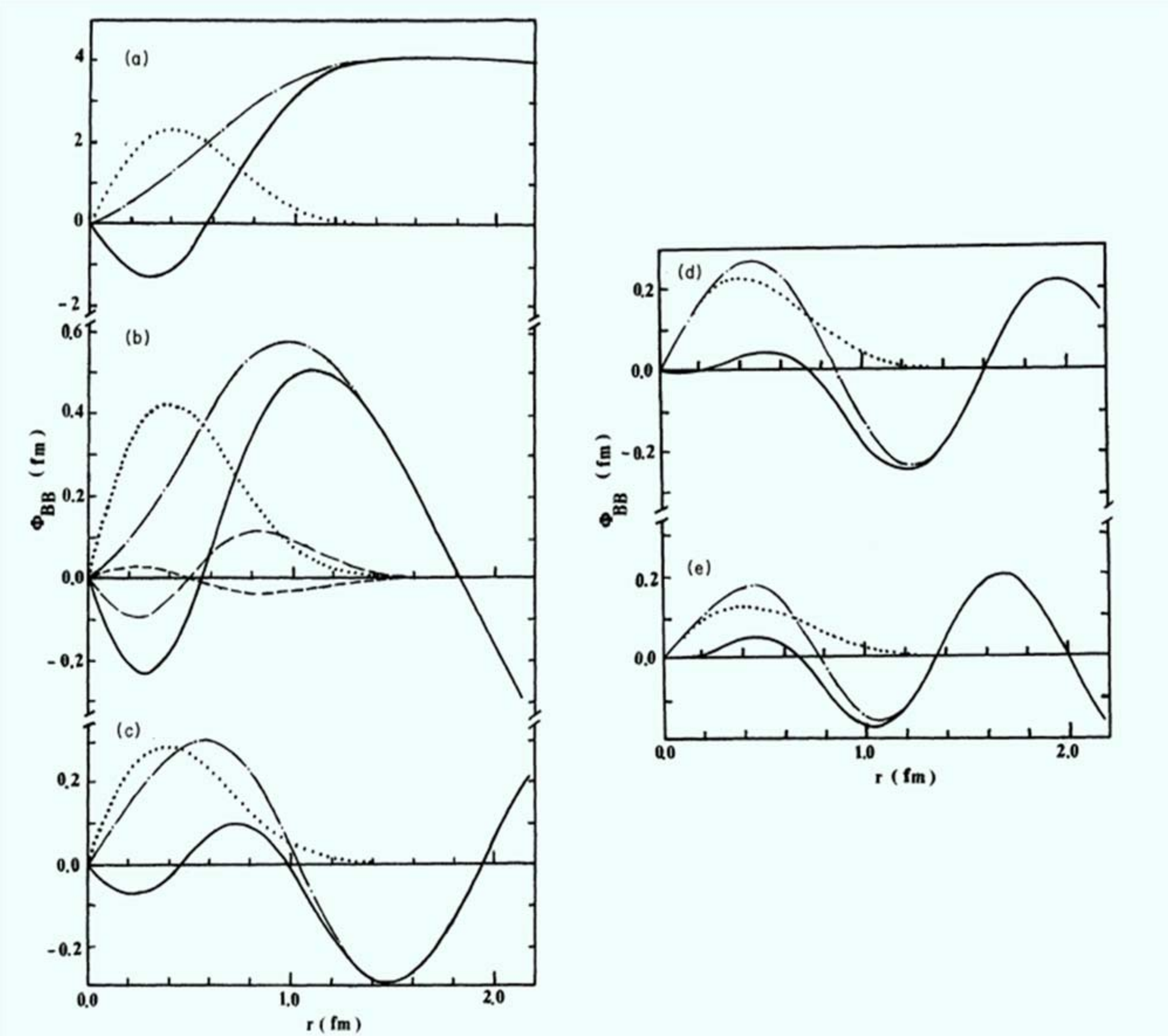
Here we will focus mainly on the symmetry aspects rather than details of quark dynamics.



So, the mixed symmetry 6q-configuration $|s^4p^2[42]_x>$ is strongly dominating over the fully symmetric one $|s^6[6]_x>$ as:

W([42]):W([6])=8:1 (for two non-interacting nucleons)

- It was proved (Y.Yamauchi, A.Buchmann, A.Faessler; I.T.Obukhovsky, O.Kusainov; M.Oka, K.Yazaki and many others) that this dominating mixed-symmetry configuration is preserved also for any reasonable *qq* interaction model.



ne mixed symmetry configuration $|s^4p^2[42]_x>$ gives, when projecting into NN channel, a nodal projection $\chi_{NN}([42],r)$ while $|s^6[6]_x>$ gives a nodeless projection $\chi_{NN}([42],r)$.

Thus, in quark model one has the nodal relative motion NN wf in S- and P-waves at low energies.

The projection of 6q wavefunctions with different symmetry onto NN channel. Projection of total wf (dot-dashed line) and its components s^4p^2 (solid line) and s^6 (dotted line) are shown at energies E_{lab}=5 (a), 200 (b), 1000 (c), 1500 (d) and 2000 MeV (e). Projection of wf onto ΔΔ-channel (dashed line) and *cc* channel (long-dashed line) are also shown at E_{lab}=200 MeV.

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Nucleon-nucleon interaction in a chiral constituent quark model

Fl. Stancu and S. Pepin
Université de Liège, Institut de Physique B.5, Sart Tilman, B-4000 Liège 1, Belgium

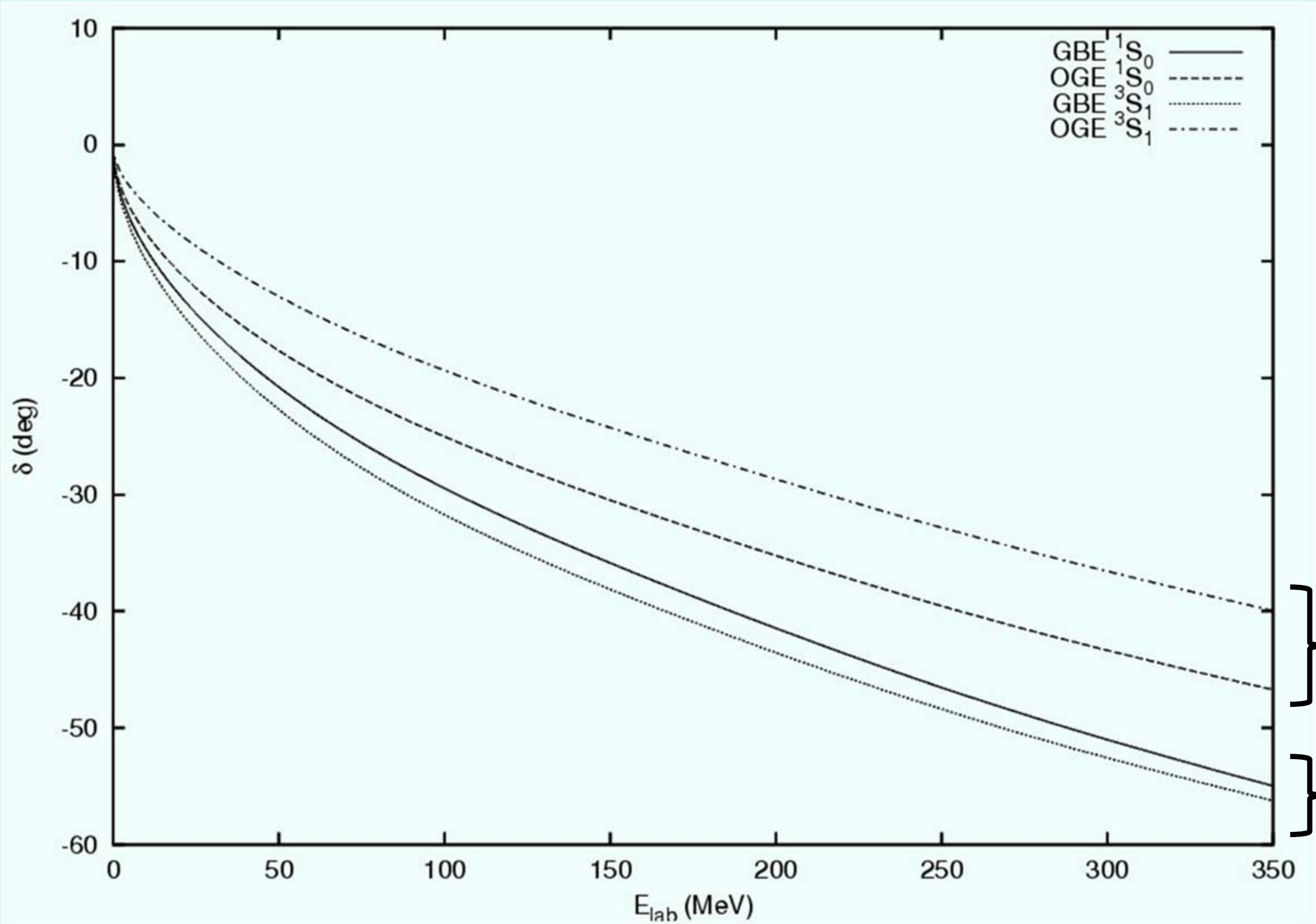
L. Ya. Glozman
Institute for Theoretical Physics, University of Graz, 8010 Graz, Austria

"We show that the highly dominant configuration is $|s^4p^2[42]_O\,[51]_{FS}\rangle$ due to its specific flavour-spin symmetry. Using the Born-Oppenheimer approximation we find a strong effective repulsion at zero separation between nucleons in both $^3S_1$ and $^1S_0$ channels. The symmetry structure of the highly dominant configuration implies the existence of a node in the S-wave relative motion wave function at short distances. The amplitude of the oscillation of the wave function at short range will be however strongly suppressed."

"The main outcome is that $V_{NN}(R=0)$ is highly repulsive in both $^3S_1$ and $^1S_0$ channels, the height being 0.830 GeV in the former case and 1.356 GeV in the latter one."

"Thus it is the GBE interaction which brings about 1 GeV repulsion, consistent with the previous discussion."

The nucleon-nucleon phase shifts found with GBE-and OGE-models for q-q force



OGE *qq* force

GBE *qq* force

However, if to add (by hands) an additional scalar force (on qq or directly on NN level) one can describe properly the empirical NN phase shifts. But still the scattering wavefunctions in this model will have inner stationary nodes in lowest NN partial waves.

This behaviour is not compatible with traditional repulsive core NN potentials.

So is it possible to describe the nodal behaviout with any potential?

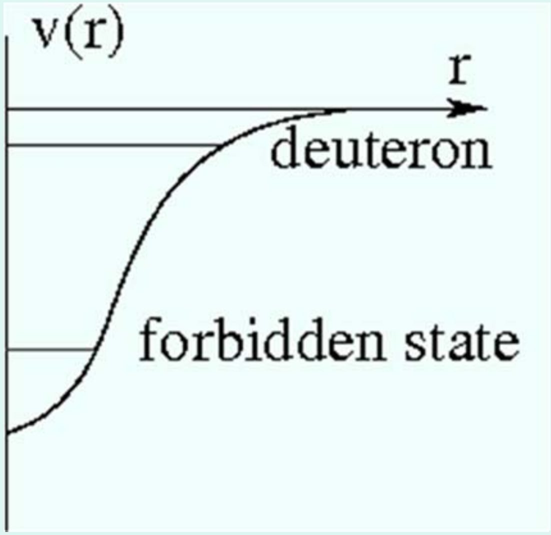
Thus, the NN potential corresponding to this situation should be strongly attractive one with 0*s* forbidden state. It is so called Moscow NN potential, see e.g.:

V.I.Kukulin, V.M.Krasnopolsky, V.N.Pomerantsev, P.B.Sazonov

– Sov.J. Nucl. Phys. **43**, 355 (1986); Phys. Lett. **B135**, 20 (1984);

V.I.Kukulin, V.N.Pomerantsev – Progr. Theor. Phys. (1991).

Later on the Moscow model was generalized to all other NN partial waves.



The generalized Moscow NN potential

The potential consists out of three parts:

$$v_{NN} = v_M^{loc} + v^{OPE} + v^{\text{sep}}$$

where the local exponent well v_M^{loc} depends on the channel spin and parity:

$$v_M^{loc}(r) = V_0 \exp(-\beta r) + (\mathbf{sl}) V_0^{ls} \exp(-\beta_1 r).$$

The separable repulsive part is state-dependent:

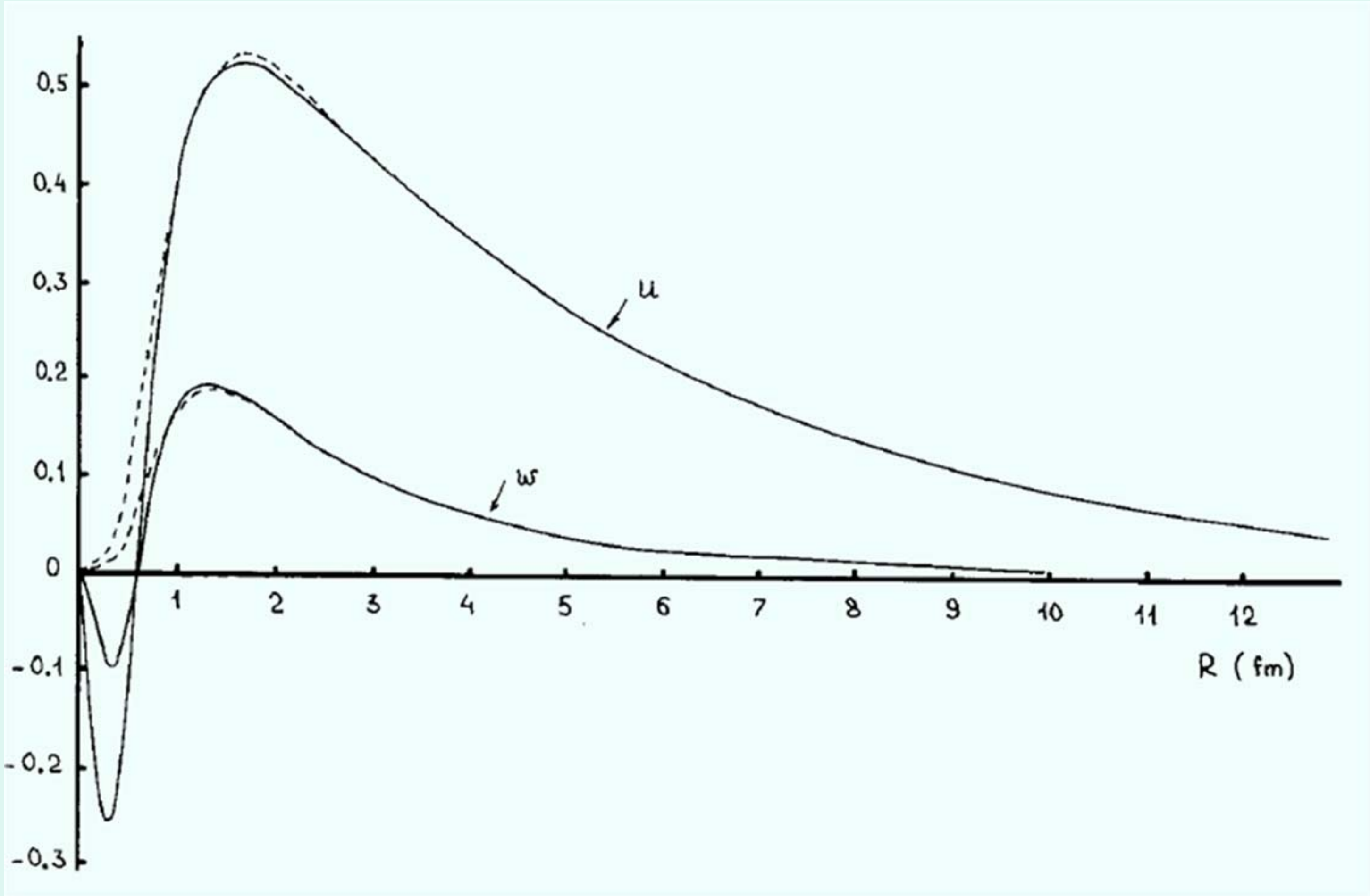
$$v^{\text{sep}} = \lambda |\varphi >< \varphi|,$$

where $|\varphi\rangle$ is a Gaussian form factor:

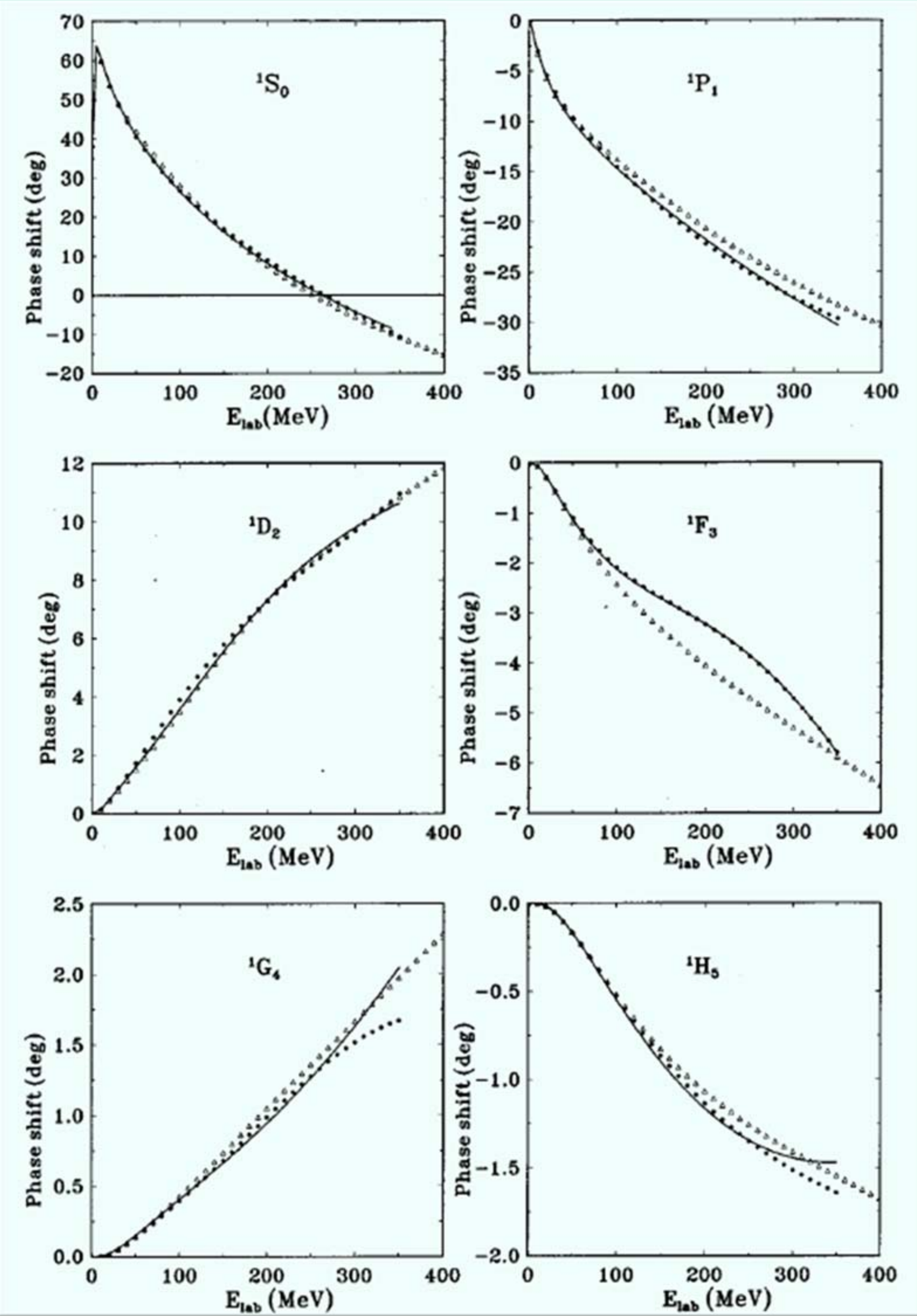
$$\varphi(r) = N r^{l+1} \exp\left(-\frac{1}{2}\left(\frac{r}{r_0}\right)^2\right)$$

with normalization condition $\int \varphi^2 dr = 1$.

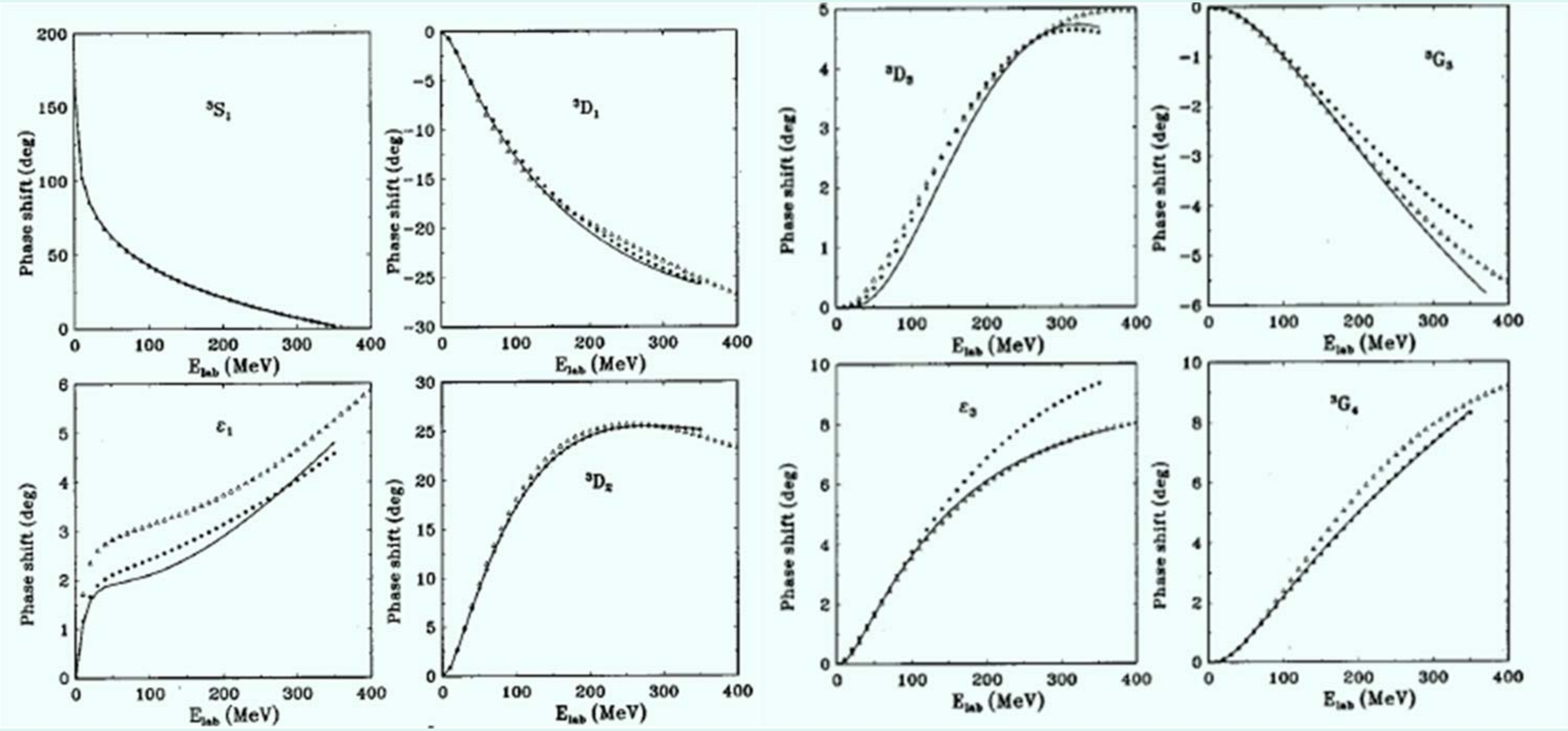
Deuteron wavefunctions in conventional (dashed lines) and Moscow (solid lines) NN potential models.



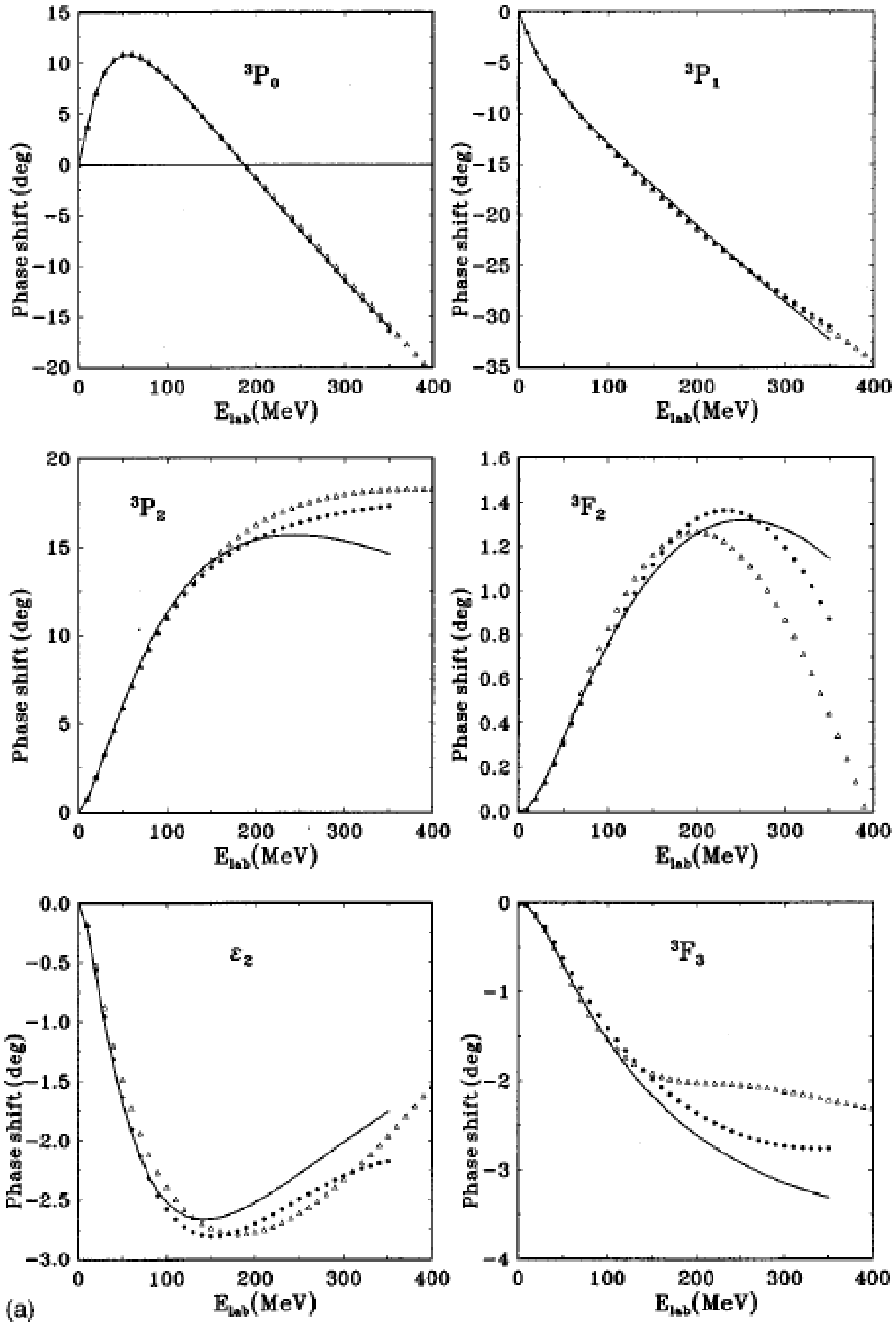
The Moscow NN potential described the lowest NN phase shifts not worse (or even better) than the conventional OBE-like potentials (Paris, RSC etc.).



NN spin-singlet phase shifts for generalized Moscow potential in comparison with the data of the energy-dependent phase-shift analyses: Nijmegen-PWA93 (circles) and SAID97 (triangles).



NN spin-triplet even-parity phase shifts for generalized Moscow potential in comparison with the data of the energy-dependent phase-shift analyses: Nijmegen-PWA93 (circles) and SAID97 (triangles).



NN spin-triplet odd-parity phase shifts for generalized Moscow potential in comparison with the data of the energy-dependent phase-shift analyses: Nijmegen-PWA93 (circles) and SAID97 (triangles).

Thus, in the mid of 80ies we had two alternative ways to describe the basic features of NN interaction:

(i) the traditional OBE-like potentials with repulsive core, and

(ii) the nonconventional deep potential with some extra bound states.

Now the question arises: what is interrelation between the deep (Moscow) and shallow (e.g. Paris) NN potentials?

From the first glance these two models look to be fully different and are not related to each other!

However! They turned out very tightly coupled by means of supersymmetrical quantum mechanics.

Supersymmetrical quantum mechanics. Basic references.

- E. Witten, Nucl.Phys. **B188** (1981) 513.
- C.V. Sukumar, J.Phys. **A18** (1985) 2917, 2937.
- A.A. Andrianov, N.V. Borisov, M.I. Ioffe, Phys. Lett. **105A** (1984) 19.
- L.E. Hendenstein, JETP Lett. **39** (1984) 234.
- J. Fuchs, J. Math. Phys. **27** (1986) 349.

Supersymmetrical quantum mechanics

$\{Q_i\}$ – charge operators, $i = 1, \ldots N$, Q_i satisfy to some algebra:

$$\begin{cases} \{Q_i, Q_j\} & = & \delta_{ij}\mathcal{H}; \quad i, j = 1, \ldots N \\ [Q_i, \mathcal{H}] & = & 0 \end{cases}$$

$\mathcal{H}$ – supersymmetrical Hamiltonian (is included in generators!)

In the simplest algebraic system with only two charge operators

$$Q_1 \text{ and } Q_2$$

$$\text{let's define: } Q = (Q_1 + iQ_2)/\sqrt{2}; \qquad Q^\dagger = (Q_1 - iQ_2)/\sqrt{2},$$

then one obtains: $\mathcal{H} = \{Q, Q^\dagger\}$

it may be considered as a definition of supersymmetrical Hamiltonian $\mathcal{H}$.

The charge operators Q are nilpotent: $Q^2 = 0$, $(Q^\dagger)^2 = 0$; then: $[Q\mathcal{H}] = [Q\mathcal{H}^\dagger] = 0$.

Some realization of superalgebra (E. Witten,1981):

$$Q = \begin{pmatrix} 0 & 0 \\ A^- & 0 \end{pmatrix}; \qquad Q^\dagger = \begin{pmatrix} 0 & A^+ \\ 0 & 0 \end{pmatrix};$$

A^- - the linear differential operator; A^+ − its conjugate. $Q^2 = 0$ by construction.

No statement about commutator: $[A^+, A^-] =?$

Then from the definition of supersymmetrical Hamiltonian we obtain:

$$\mathcal{H} = \{Q, Q^\dagger\} = \begin{pmatrix} \underbrace{A^+A^-}_{H_1} & 0 \\ 0 & \underbrace{A^-A^+}_{H_2} \end{pmatrix} = \begin{pmatrix} H_1 & 0 \\ 0 & H_2 \end{pmatrix},$$

where H_1 and H_2 are supersymmetrical partners of each other.

$$H_1 = T + U_1, \qquad H_2 = T + U_2.$$

In supersymmetrical quantum mechanics it can be proved the property of the factorization of the Hamiltonian:

$$H_2 \Rightarrow A_0^-(E_0) \cdot A_0^+(E_0) + \underbrace{E_0}_{\text{factorization energy}}$$

$$A_0^-(E_0) = \left(-\frac{\mathrm{d}}{\mathrm{d}r} + \frac{\mathrm{d}\ln\psi_0}{\mathrm{d}r}\right);\ A_0^+ = (A_0^-)^\dagger$$

Let $H_2 \equiv H_0$ (resignation) $= T + U_0$(deep attractive potential)
Normalized eigenfunctions of H_0 and H_1 are interrelated directly:

$$\Psi_1(E) = \frac{1}{\sqrt{E - \varepsilon_0}} A_0^- \Psi_0(E);\ E > \varepsilon_0 = E_0^{(0)}$$

The choice $E_0^{(0)} = \varepsilon_0$ (factorization energy) leads to almost full coincidence of the spectra H_0 and H_1 except ground state in H_0, which vanishes.

The method of factorization for Hamiltonian (so called Darboux transformation) was suggested still by Schrödinger in 1940 year. The direct interrelation between two phase-shift equivalent potentials (i.e. $U_0(r)$ and $U_2(r)$) is:

$$U_2(r) = U_0(r) - 2\frac{\hbar^2}{2\mu}\frac{\mathrm{d}^2}{\mathrm{d}r^2}\ln[\psi(E_0)\psi_1(E_0)].$$

This potential has the same spectrum (except ground state) and is fully phase-shift equivalent to U_0.

$$U_2(r) \underset{r\to 0}{\Rightarrow} \frac{2\cdot 3}{r^2}, \text{ when excluding } S\text{-wave state}$$

In general case: $U_2(r) \underset{r\to 0}{\Rightarrow} \frac{(L+2)(L+3)}{r^2}$ – in agreement with Levinson theorem!

$$\text{I.e. } U_2 \underset{\text{SUSY partner}}{\Longleftrightarrow} U_0$$

Then one can prove (D. Baye):

$H_1 = A_0^+ A_0^- + E_0 \Leftarrow$ deep attractive Hamiltonian with a forbidden state

$$H_2 = A_0^- A_0^+ + E_0 \Leftarrow \text{standard repulsive core Hamiltonian}$$

In essence, these Hamiltonians represent simply different components of unified supersymmetrical interaction.

Since $Q \begin{pmatrix} \alpha \\ 0 \end{pmatrix} = \begin{pmatrix} 0 \\ A^- \alpha \end{pmatrix}$ and $Q^\dagger \begin{pmatrix} 0 \\ \beta \end{pmatrix} = \begin{pmatrix} A^+ \beta \\ 0 \end{pmatrix}$,

one can say that the charge operators Q and $Q^\dagger$ induce transformation between bosonic (α) and fermionic (β) sectors.

Z. Phys. A – Atomic Nuclei 329, 385–392 (1988)

Zeitschrift für Physik A
Atomic Nuclei

Connection of Kukulin's Nucleon-Nucleon Deep Potential with Realistic Repulsive Core Interactions

F. Michel[1] and G. Reidemeister[2]*

[1]Faculté des Sciences, Université de l'Etat à Mons, Belgium
[2]Physique Nucléaire Théorique, Université Libre de Bruxelles, Belgium

$^3S_1$-$^3D_1$ Moscow and SUSY partner potentials

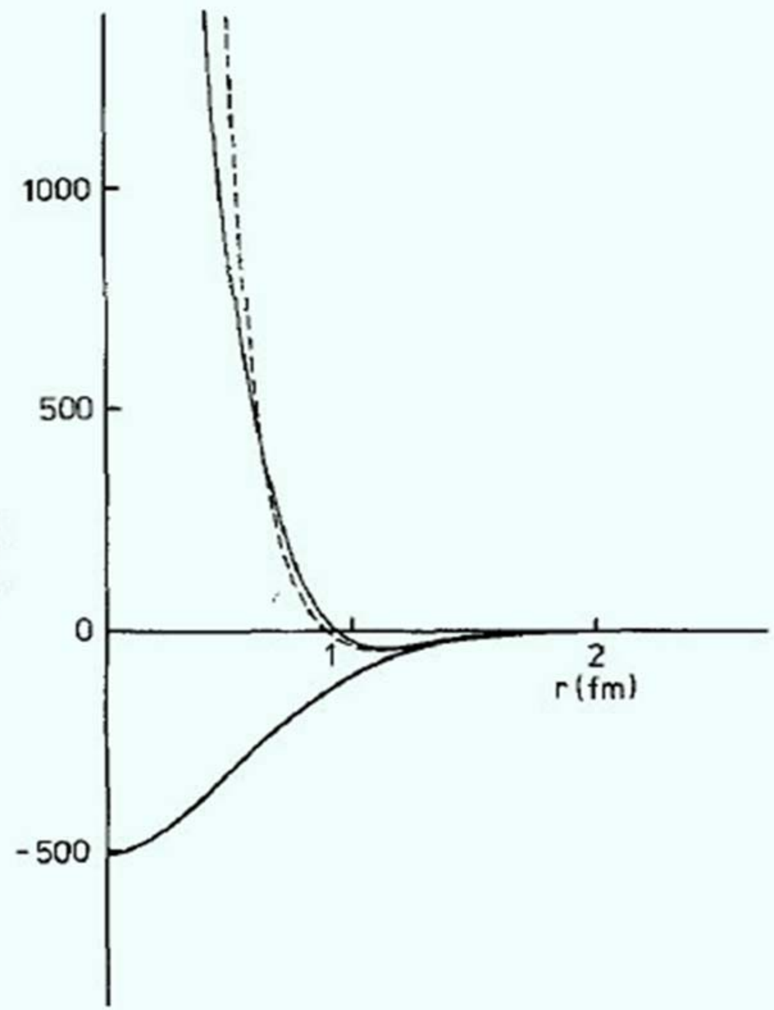


Fig. 5. Comparison of the nucleon-nucleon triplet central potential of Kukulin et al. [2] (thick line) with our reconstructed potential (thin line) and with the Reid soft core interaction [20] (dashed line)

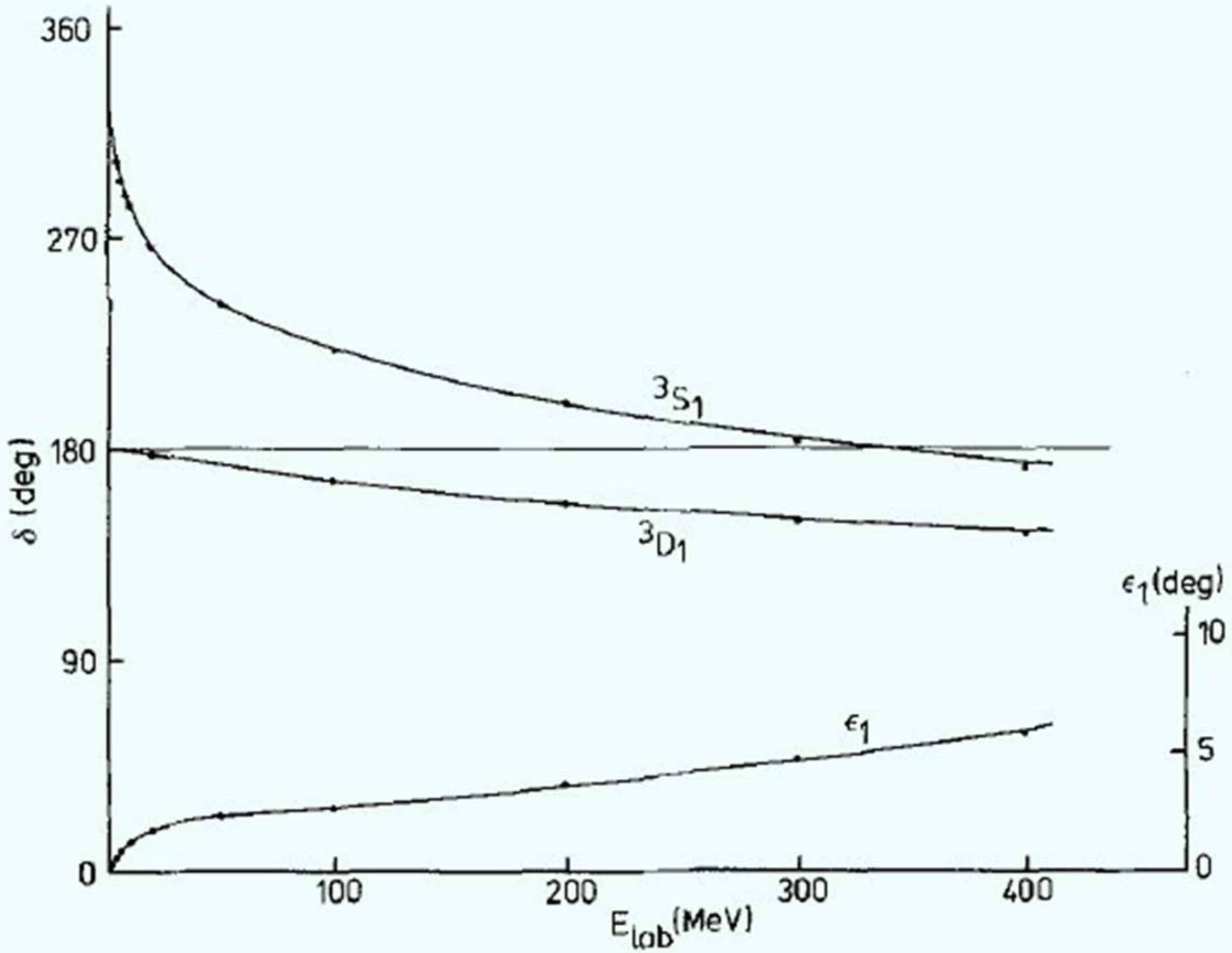


Fig. 4. Nucleon-nucleon $^3S_1$ and $^3D_1$ phase shifts and mixing parameter ε_1, calculated with the interaction of Kukulin et al. [2] (full lines) and with our reconstructed potential (dots) (the phase shifts are represented up to a translation of π)

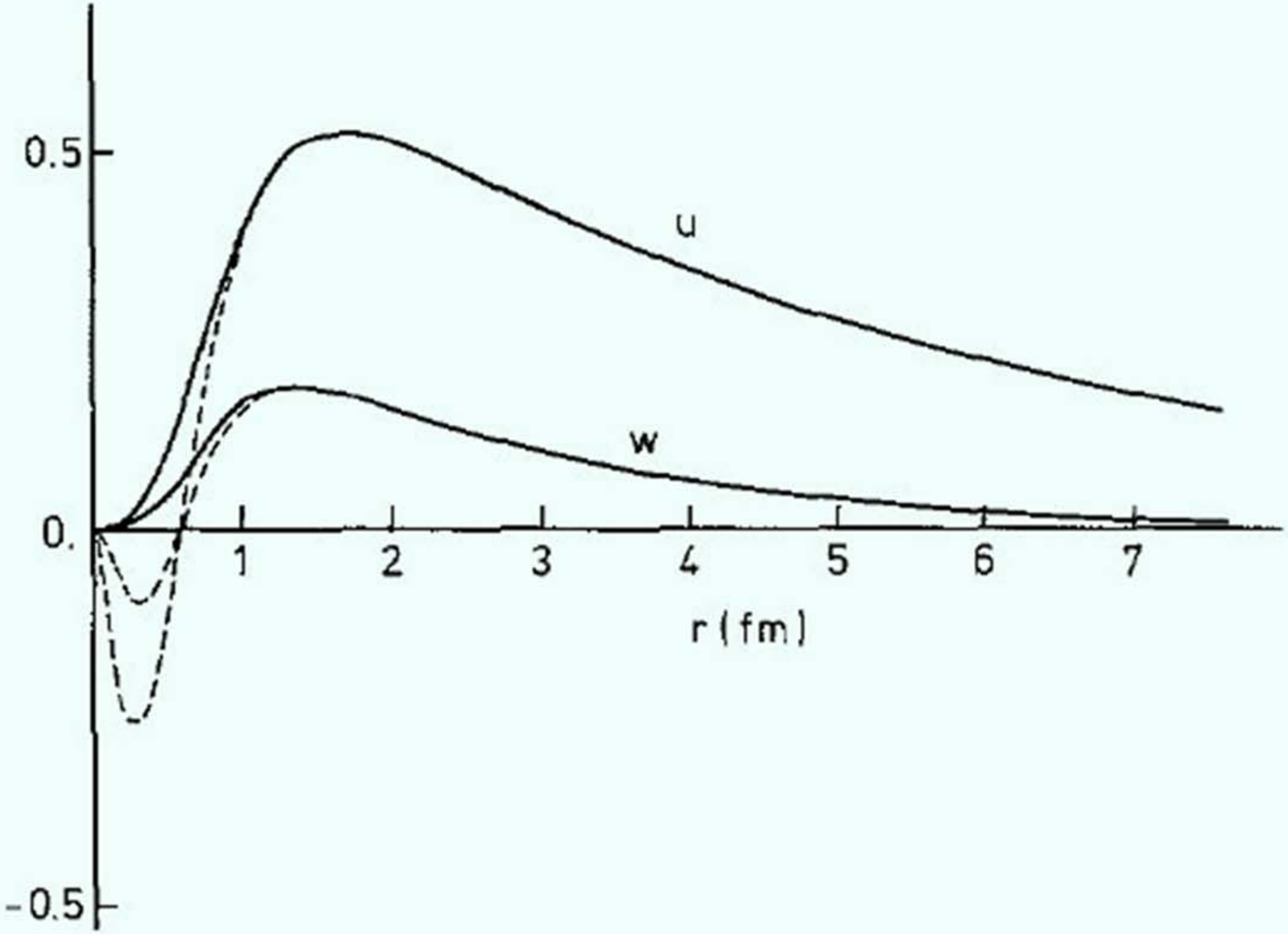


Fig. 7. Deuteron wave function components *u* and *w* calculated with the potential of Kukulin et al. [2] (dashed line) and with our reconstructed potential (full line)

Table 1. Comparison of the deuteron observables calculated with the potential of Kukulin et al. [2] and with our reconstructed potential using as cutoff parameters $R_t = 0.8015$ fm, $a_t = 0.15$ fm (see text)

Parameter	Kukulin's potential	Reconstructed potential
E_d(MeV)	2.225	2.225
$\langle r_d^2 \rangle^{1/2}$(fm)	1.961	1.968
P_D(%)	6.78	6.68
Q(fm^2)	0.286	0.288
$\eta = A_D/A_S$	0.0269	0.0268
A_S	0.881	0.886

$^1S_0$ Moscow and SUSY partner potentials

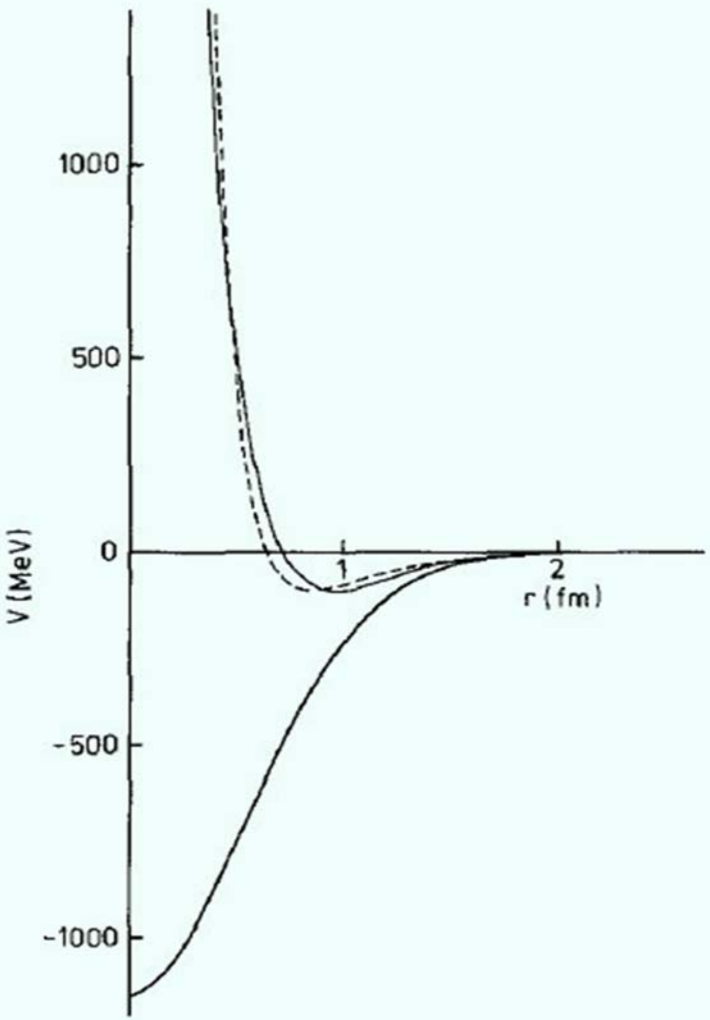


Fig. 2. Comparison of the nucleon-nucleon singlet central potential of Kukulin et al. [2] (thick line) with our reconstructed potential (thin line) and with the Reid soft core interaction [20] (dashed line)

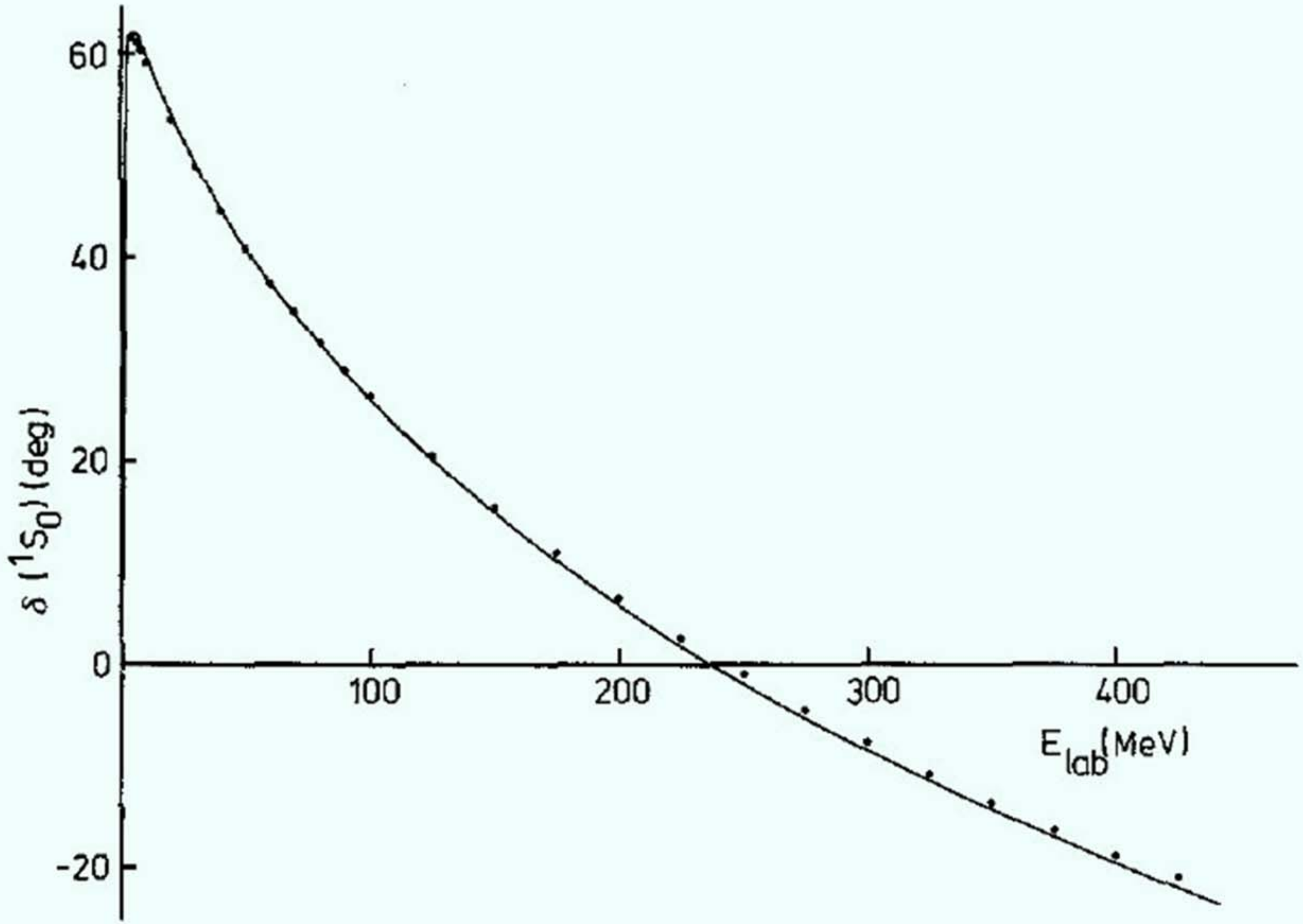


Fig. 1. Nucleon-nucleon $^1S_0$ phase shift calculated with the interaction of Kukulin et al. [2] (full line) and with our reconstructed potential (dots) (the full line has been shifted downwards by π)

So, there is a very deep interrelation (based on supersymmetry) between two (seemingly fully different) NN force models.
What is physical origin for this supersymmetry?

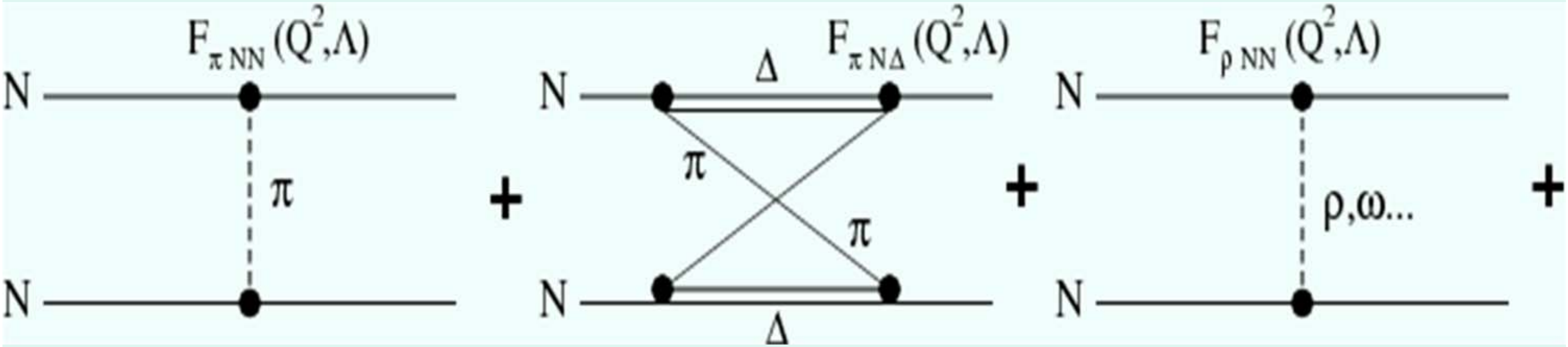
The almost evident reply is the intermediate 6q bag which is boson. So, in this case two nucleons (fermions), when interacting, are fusing into a boson (6q) and then the intermediate boson breaks into two other! nucleons.
However, as was demonstrated above the intermediate 6q bag (if to choose the *qq* force to be compatible with all baryonic spectra (e.g. the Goldstone-boson-exchange model) leads only to purely repulsive NN potential (i.e. it gives no attraction needed to bind deuteron and other nuclei)!
So one needs some new alternative model for the intermediate 6q bag where the bag formation can lead to strong NN attraction at r_{NN}=1 fm.
This is doing by the dressed dibaryon model proposed in our group 10 years ago.

Dibaryon concept for nuclear force and its experimental evidence

1. Yukawa's picture for nuclear force and its difficulties
2. Hard problems with 2π-exchange and scalar force.
3. Dibaryon mechanism for scalar field generation in Roper resonance and in NN system.
4. Experimental evidence.
5. New three-body force based on dibaryon mechanism. Nonconventional picture for nuclei.
6. Conclusion.

Yukawa's conception for the nuclear force

Nowadays the traditional model for the NN-interaction and basic nuclear force, which has been based on the Yukawa's idea on the meson-exchange in *t*-channel, works very well at large distances $r_{NN} > \lambda_\pi \sim 1.4$ fm but there are some serious problems and fundamental difficulties at intermediate ($r_{NN} \sim 1$ fm) and especially at short ranges ($r_{NN} \sim 0.4 - 0.8$ fm).

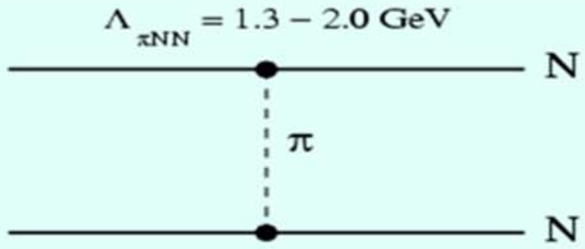


The intermediate- and short-range nuclear force should be revised somehow.

The most appropriate, consistent and related to fundamental QCD-picture way to make the revision is an introduction of the dibaryon degree of freedom in hadronic physics, NN interaction and generally in nuclear physics.

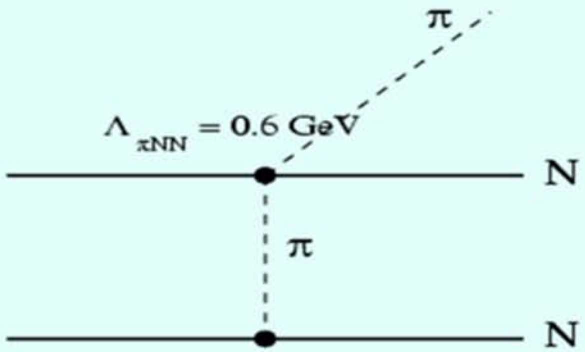
The problems in OBE-description of intermediate range interaction:

1. $\Lambda_{\pi NN}$ (in all OBE-models)$\simeq 1.3 \div 2.0$ GeV is very high and in strong disagreement with all microscopic theoretical estimates and experimental fits ($\Lambda_{\pi NN}|_{\text{exp}} \sim 0.5 \div 0.8$ GeV). Moreover, the cut-off parameters $\Lambda_{\pi NN}$ and $\Lambda_{\rho NN}$, which fit the inelastic NN-data on π-meson production, like $pp \to pp\pi^0$ or $pn\pi^+$, are in good agreement just with the soft values of $\Lambda_{\pi NN} \simeq 0.5 \div 0.6$ GeV!

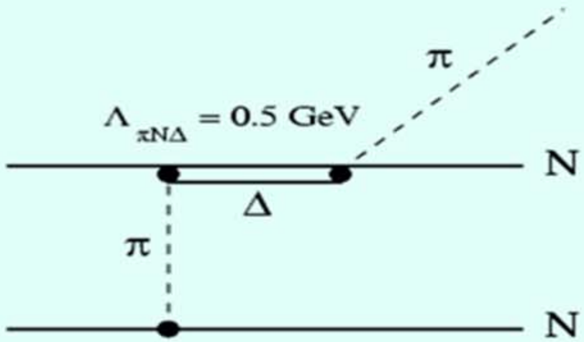


elastic channel

but

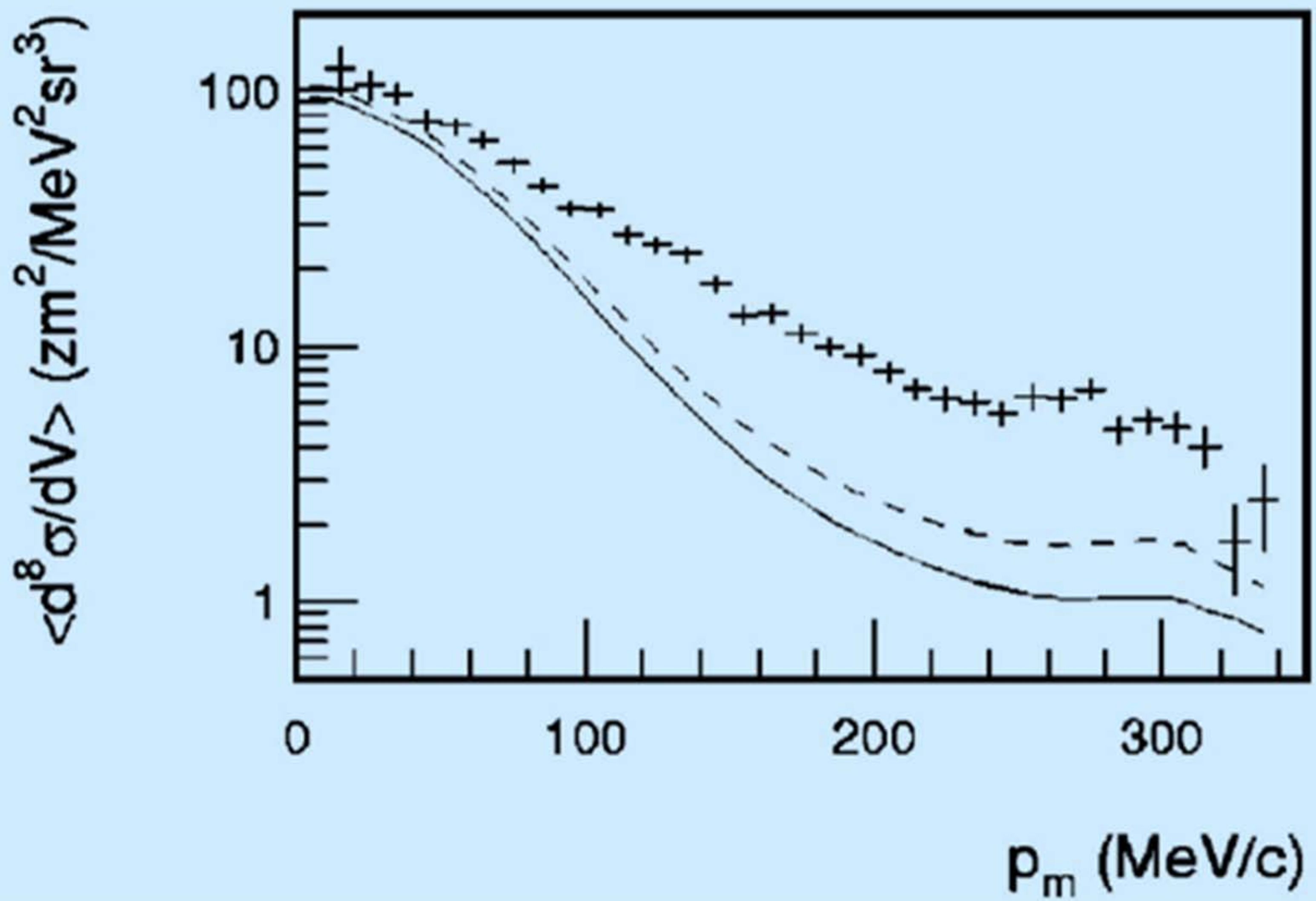


inelastic channel



inelastic channel

The average $^3He(e,e'pp)$ cross section as a function of missing momentum p_m at E_e = 750 MeV (the data of NIKHEF). The theoretical predictions without (solid line) and with (dashed line) pair 2N currents are based on full Faddeev 3N calculations with three-nucleon force included



The comparison for the $^4He(e,e'p)^3H$ cross section between experimental data and Laget calculations with PWIA, PWIA+FSI PWIA+FSI+MEC. Disagreement is large !

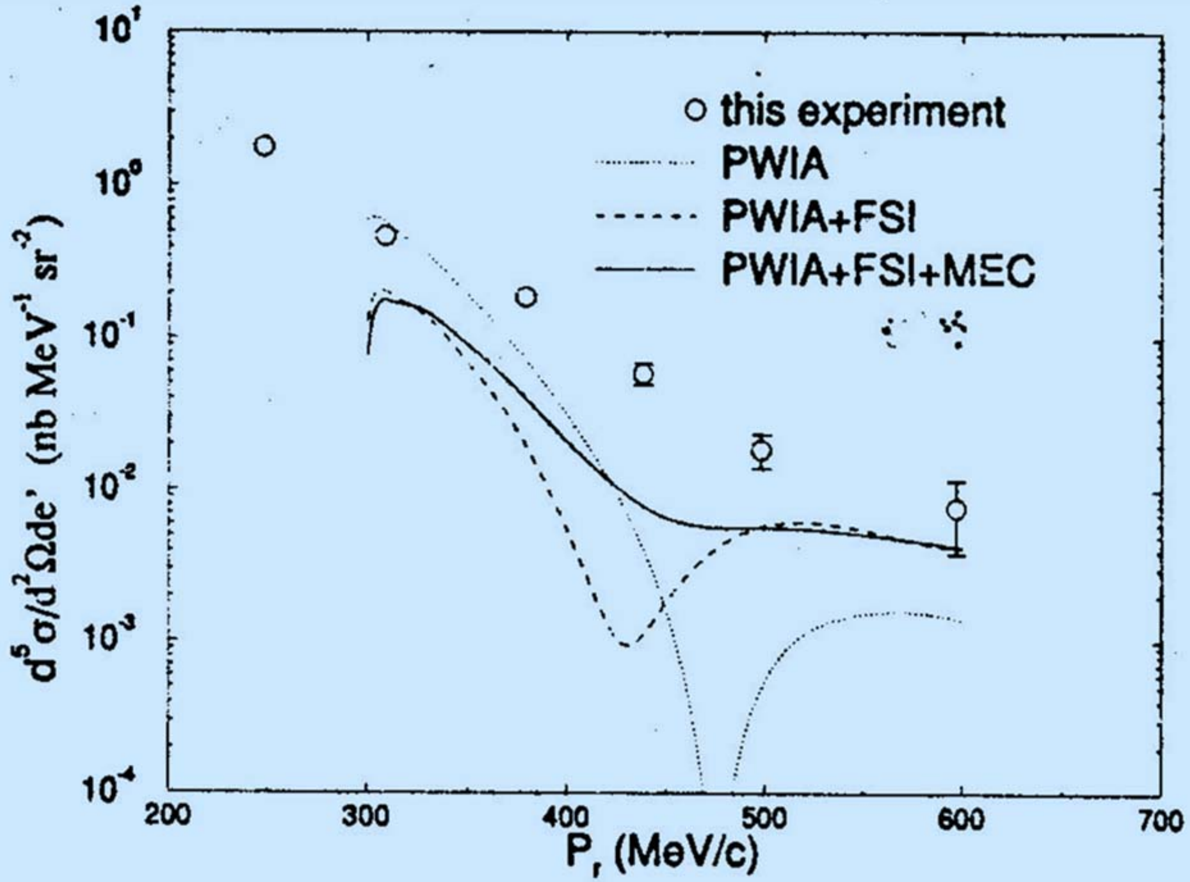
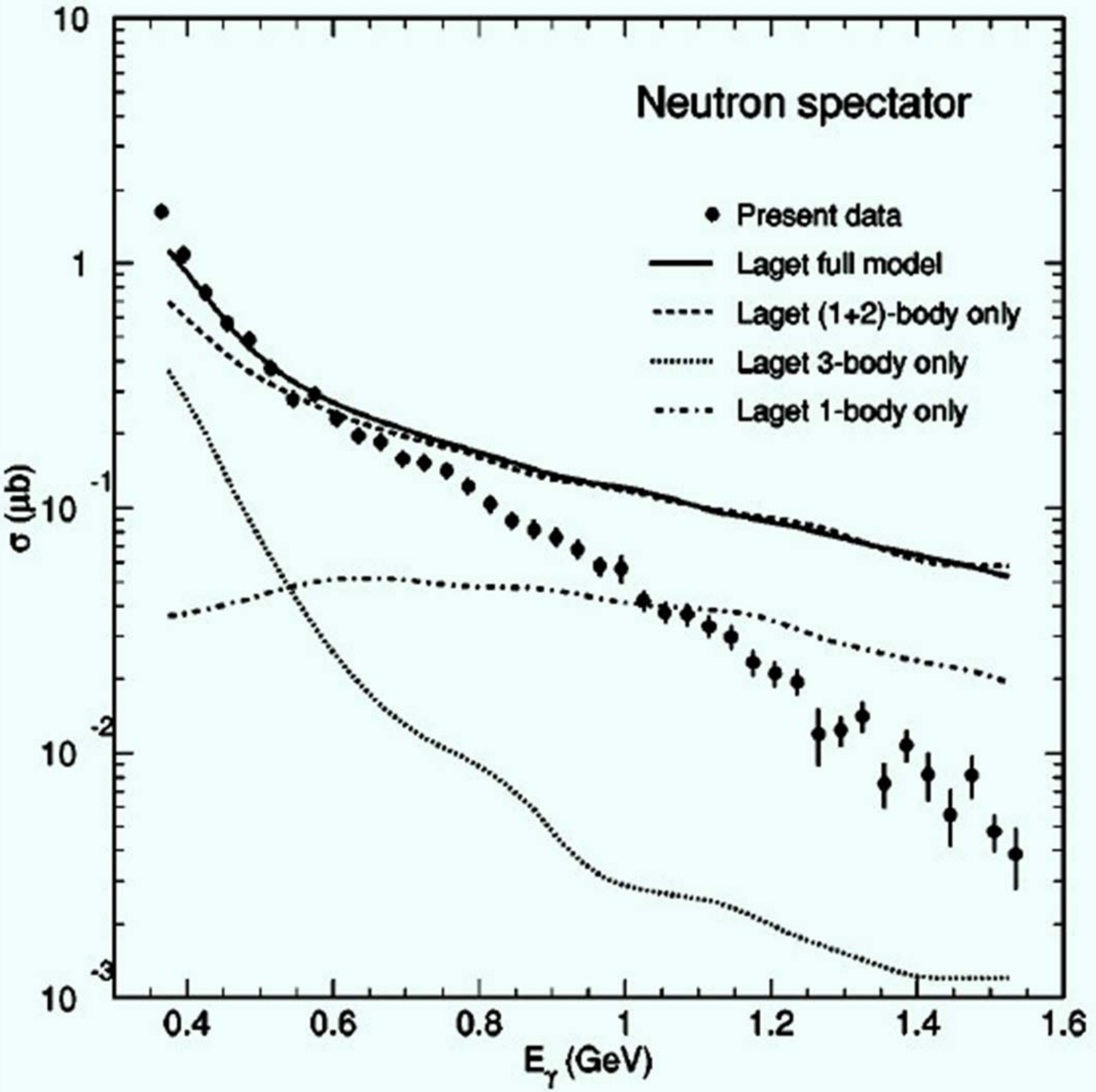


FIG. 3. Radiatively corrected cross section in the 2bbu channel. The curves are the result of a microscopic calculation based on a diagrammatic expansion of the cross section [31].

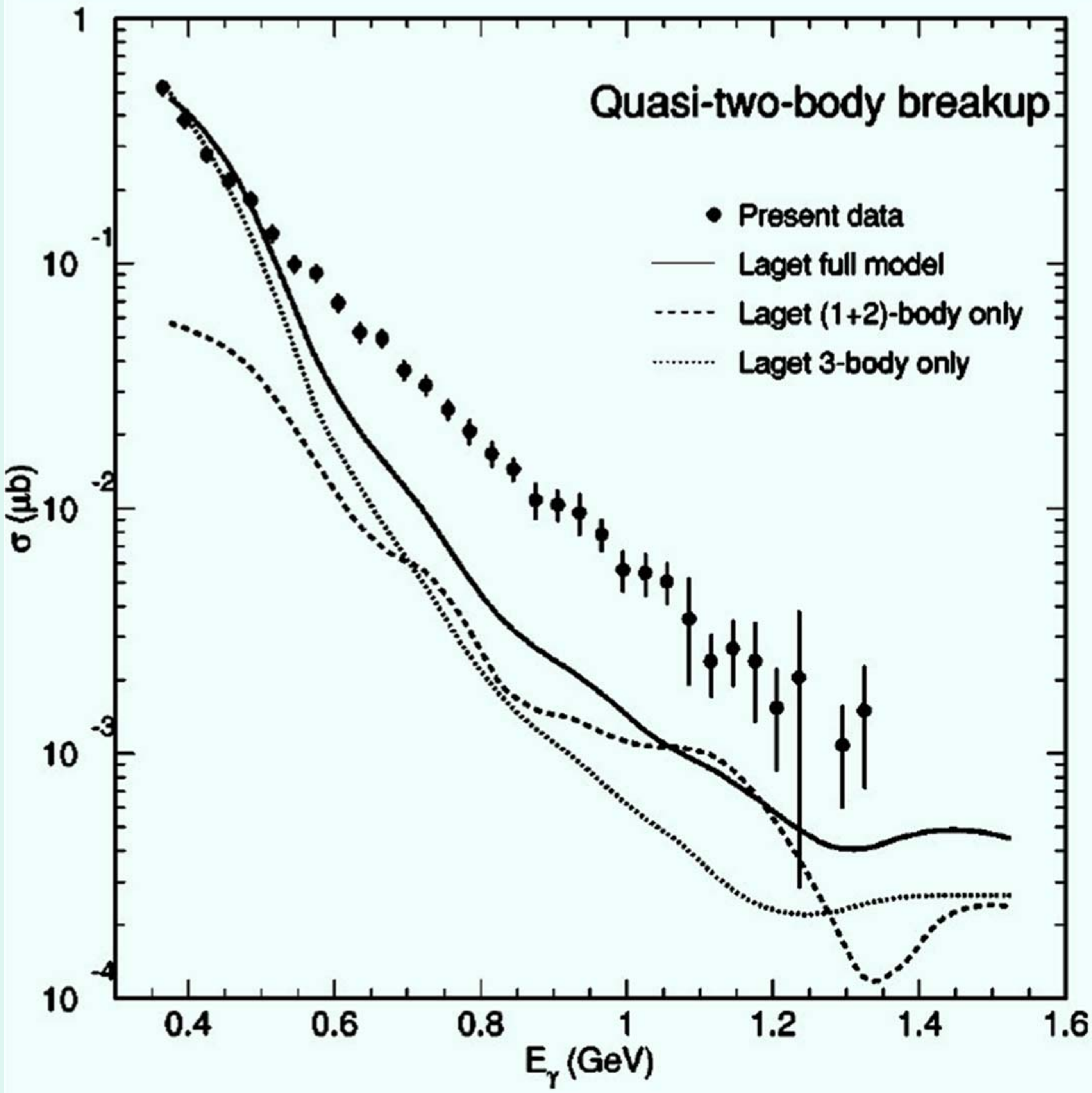
PHYSICAL REVIEW C **70**, 064003 (2004)

Complete measurement of three-body photodisintegration of ^{3}He for photon energies between 0.35 and 1.55 GeV

S. Niccolai,[2,11,*] G. Audit,[2] B. L. Berman,[11] J. M. Laget,[2] S. Strauch,[11] G. Adams,[28] A. Afanasev,[38] P. Ambrozewicz,[9] M. Anghinolfi,[15] J. R. M. Annand,[12] C. Armstrong,[33] B. Asavapibhop,[21] H. Avakian,[33] H. Bagdasaryan,[25] J. P. Ball,[1] S. Barrow,[10] M. Battaglieri,[15] K. Beard,[18] M. Bektasoglu,[25] M. Bellis,[4] N. Benmouna,[11] N. Bianchi,[14] A. S. Biselli,[4] S. Boiarinov,[33] B. E. Bonner,[29] S. Bouchigny,[16] R. Bradford,[4] D. Branford,[8] W. J. Briscoe,[11] W. K. Brooks,[33] V. D. Burkert,[33] C. Butuceanu,[37] J. R. Calarco,[22] D. S. Carman,[24] B. Carnahan,[5] S. Chen,[10] P. L. Cole,[13] A. Coleman,[37,†] D. Cords,[33,‡] P. Corvisiero,[15] D. Crabb,[36] H. Crannell,[5] J. P. Cummings,[28] E. De Sanctis,[14] R. DeVita,[15] P. V. Degtyarenko,[33] H. Denizli,[27] L. Dennis,[10] K. V. Dharmawardane,[25] K. S. Dhuga,[11] C. Djalali,[31] G. E. Dodge,[25] D. Doughty,[6] P. Dragovitsch,[10] M. Dugger,[1] S. Dytman,[27] O. P. Dzyubak,[31] H. Egiyan,[33] K. S. Egiyan,[38] L. Elouadrhiri,[33] A. Empl,[28] R. Ent,[33] P. Eugenio,[10] R. Fatemi,[36] G. Fedotov,[39] G. Feldman,[11] R. J. Feuerbach,[33] J. Ficenec,[35] T. A. Forest,[25] H. Funsten,[37] G. Gavalian,[25] G. P. Gilfoyle,[30] K. L. Giovanetti,[18] E. Golovatch,[39,15] C. I. O. Gordon,[12] R. W. Gothe,[31] K. Griffioen,[37] M. Guidal,[16] M. Guillo,[31] N. Guler,[25] L. Guo,[33] V. Gyurjyan,[33] C. Hadjidakis,[16] R. S. Hakobyan,[5] J. Hardie,[6,33] D. Heddle,[33] P. Heimberg,[11] F. W. Hersman,[22] K. Hicks,[24] K. Hleiqawi,[24] M. Holtrop,[22] J. Hu,[28] M. Huertas,[31] C. E. Hyde-Wright,[25] Y. Y. Ilieva,[11] D. Ireland,[12] M. M. Ito,[33] D. Jenkins,[35] H. S. Jo,[16] K. Joo,[7] H. G. Juengst,[11] J. Kellie,[12] M. Khandaker,[23] K. Y. Kim,[27] K. Kim,[19] W. Kim,[19] A. Klein,[25] F. J. Klein,[5] A. V. Klimenko,[25] M. Klusman,[28] M. Kossov,[17] L. H. Kramer,[9,33] Y. Kuang,[37] S. E. Kuhn,[25] J. Kuhn,[4] J. Lachniet,[4] J. Langheinrich,[31] D. Lawrence,[21] Ji Li,[28] A. C. S. Lima,[11] K. Livingston,[12] K. Lukashin,[5] J. J. Manak,[33] C. Marchand,[2] S. McAleer,[10] J. W. C. McNabb,[26] B. A. Mecking,[33] J. J. Melone,[12] M. D. Mestayer,[33] C. A. Meyer,[4] K. Mikhailov,[17] R. Minehart,[36] M. Mirazita,[14] R. Miskimen,[21] L. Morand,[2] S. A. Morrow,[2] V. Muccifora,[14] J. Mueller,[27] L. Y. Murphy,[11] G. S. Mutchler,[29] J. Napolitano,[28] R. Naseripour,[9] G. Niculescu,[18] I. Niculescu,[18] B. B. Niczyporuk,[33] R. A. Niyazov,[33] M. Nozar,[33] J. T. O'Brien,[5] G. V. O'Rielly,[11] M. Osipenko,[39,15] A. Ostrovidov,[10] K. Park,[19] E. Pasyuk,[1] S. A. Philips,[11] N. Pivnyuk,[17] D. Pocanic,[36] O. Pogorelko,[17] E. Polli,[14] I. Popa,[11] S. Pozdniakov,[17] B. M. Preedom,[31] J. W. Price,[3] Y. Prok,[36] D. Protopopescu,[12] L. M. Qin,[25] B. A. Raue,[9,33] G. Riccardi,[10] G. Ricco,[15] M. Ripani,[15] B. G. Ritchie,[1] F. Ronchetti,[14] G. Rosner,[12] P. Rossi,[14] D. Rowntree,[20] P. D. Rubin,[30] F. Sabatié,[2] C. Salgado,[23] J. P. Santoro,[35,33] V. Sapunenko,[15] R. A. Schumacher,[4] V. S. Serov,[17] A. Shafi,[11] Y. G. Sharabian,[33] J. Shaw,[21] A. V. Skabelin,[20] E. S. Smith,[33] L. C. Smith,[36] D. I. Sober,[5] A. Stavinsky,[17] S. Stepanyan,[25,38] P. Stoler,[28] I. I. Strakovsky,[11] R. Suleiman,[20] M. Taiuti,[15] S. Taylor,[29] D. J. Tedeschi,[31] U. Thoma,[33,§] R. Thompson,[27] R. Tkabladze,[24] L. Todor,[30] C. Tur,[31] M. Ungaro,[28] M. F. Vineyard,[34] A. V. Vlassov,[17] K. Wang,[36] L. B. Weinstein,[25] D. P. Weygand,[33] C. S. Whisnant,[18,31] M. Williams,[4] E. Wolin,[33] M. H. Wood,[31] A. Yegneswaran,[33] J. Yun,[25] and L. Zana[22]
(The CLAS Collaboration)

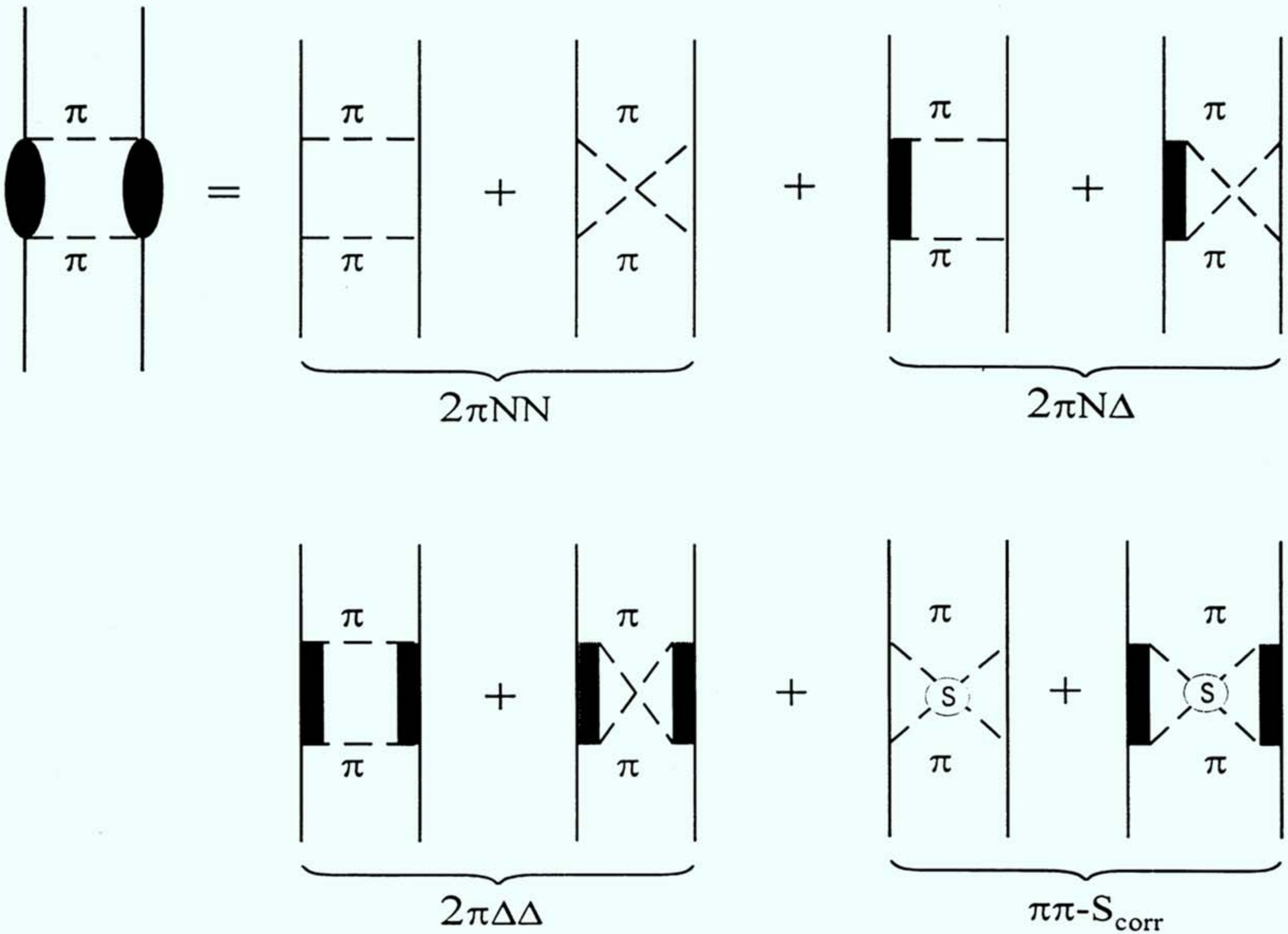


Neutron spectator
Present data
Laget full model
Laget (1+2)-body only
Laget 3-body only
Laget 1-body only
σ (μb)
10
1
10^{-1}
10^{-2}
10^{-3}
0.4
0.6
0.8
1
1.2
1.4
1.6
E_γ (GeV)

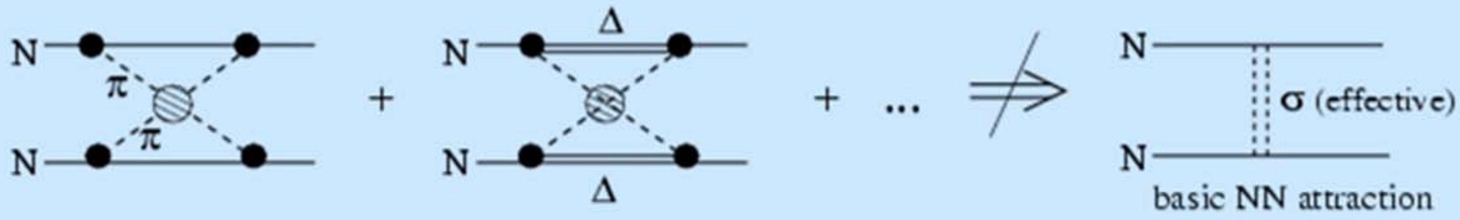


Quasi-two-body breakup
Present data
Laget full model
Laget (1+2)-body only
Laget 3-body only
σ (μb)
E_γ (GeV)
1
10^-1
10^-2
10^-3
10^-4
0.4
0.6
0.8
1
1.2
1.4
1.6

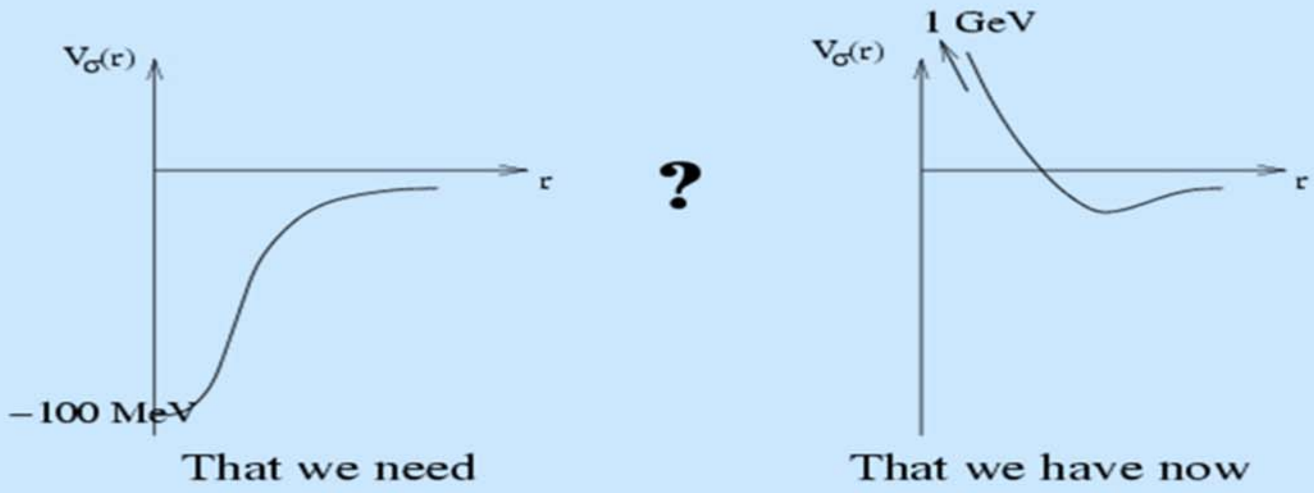
Field-theoretical model for the 2π-exchange



Puzzle with scalar meson exchange

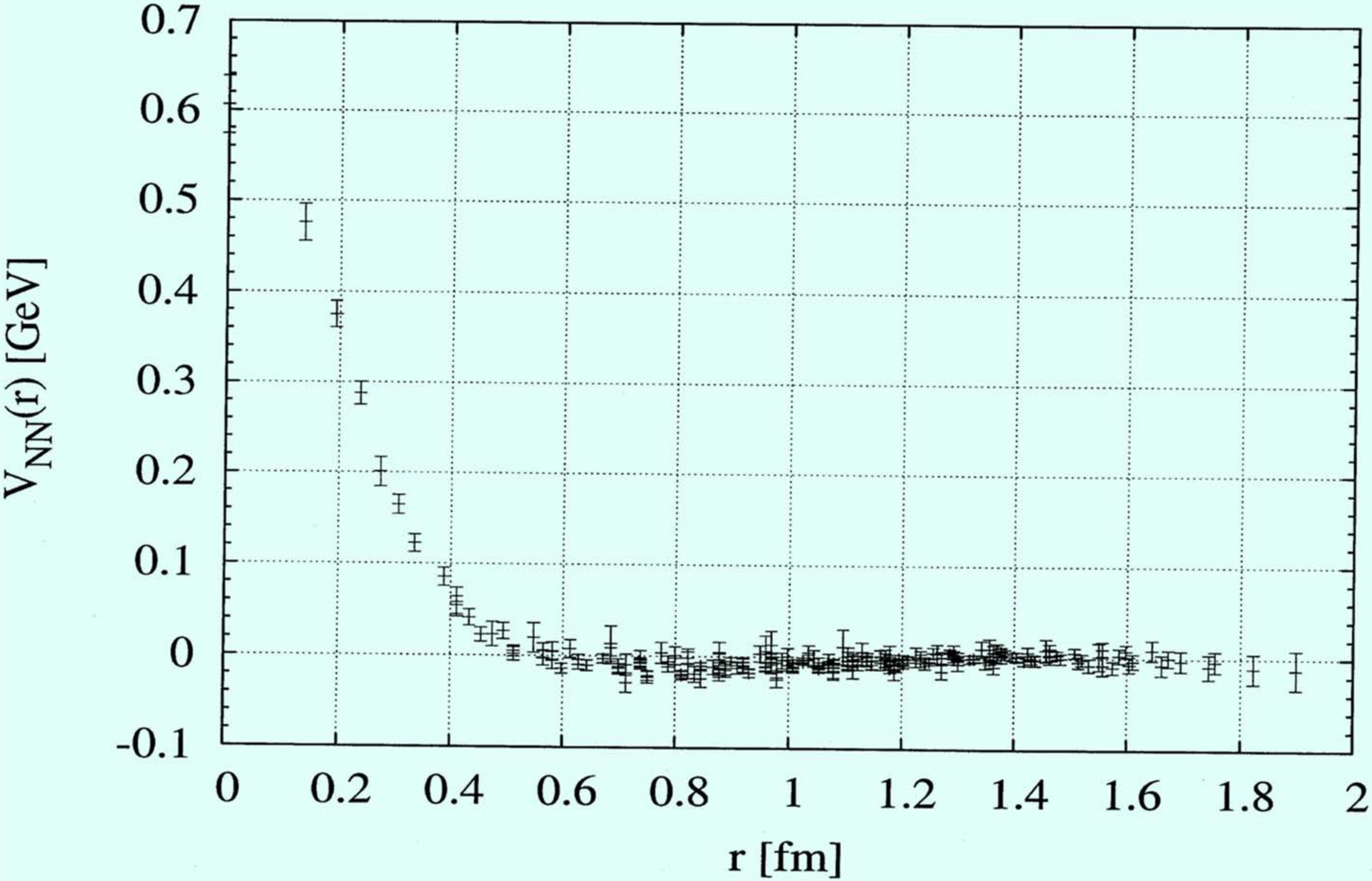


Contrary to the conventional view, the three independent groups have found that 2π-exchange with intermediate $\pi - \pi$ s-wave interaction leads to strong short- and intermediate-range repulsion and only very moderate peripheral attraction.



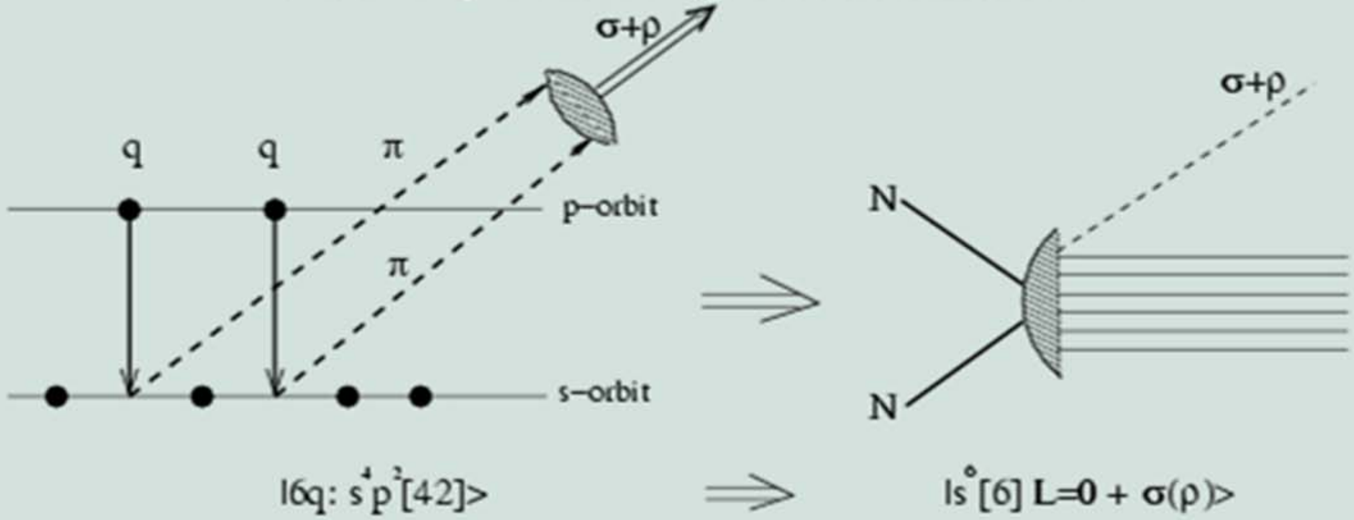
As a result, we have now NO MECHANISM FOR PROVIDING BASIC INTERNUCLEON ATTRACTION. In this point the intermediate dressed dibaryons appear!

NN potential extracted from Lattice QCD

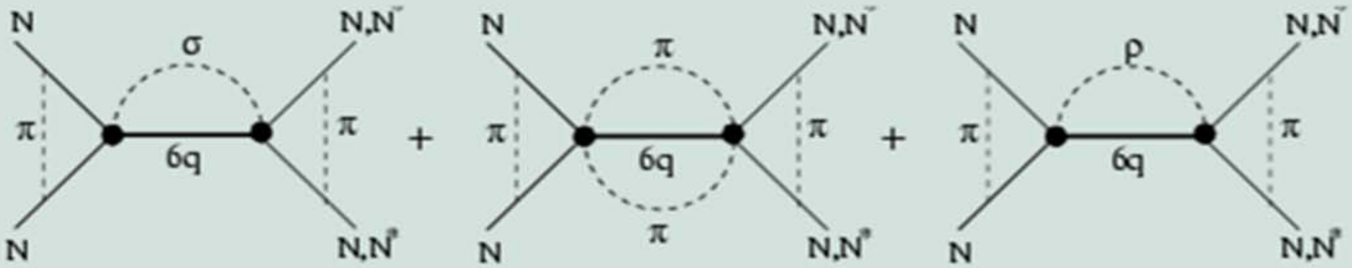


The dibaryon mechanism for scalar field generation in Roper resonance and NN system

The 6q dressing mechanism.

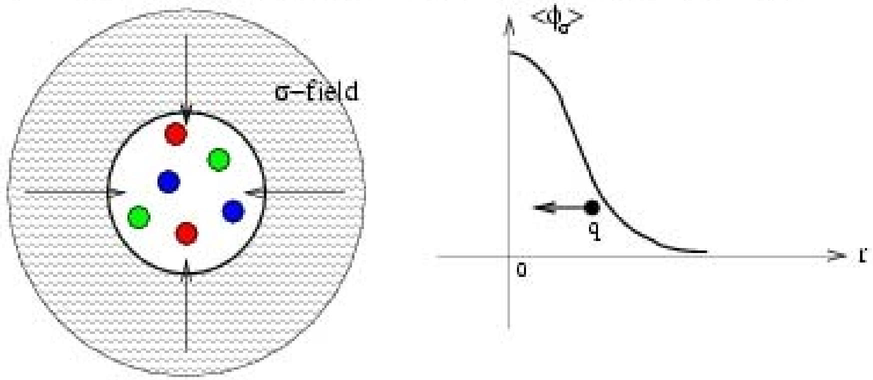


The new dressing mechanism can be presented in the form of diagrams:



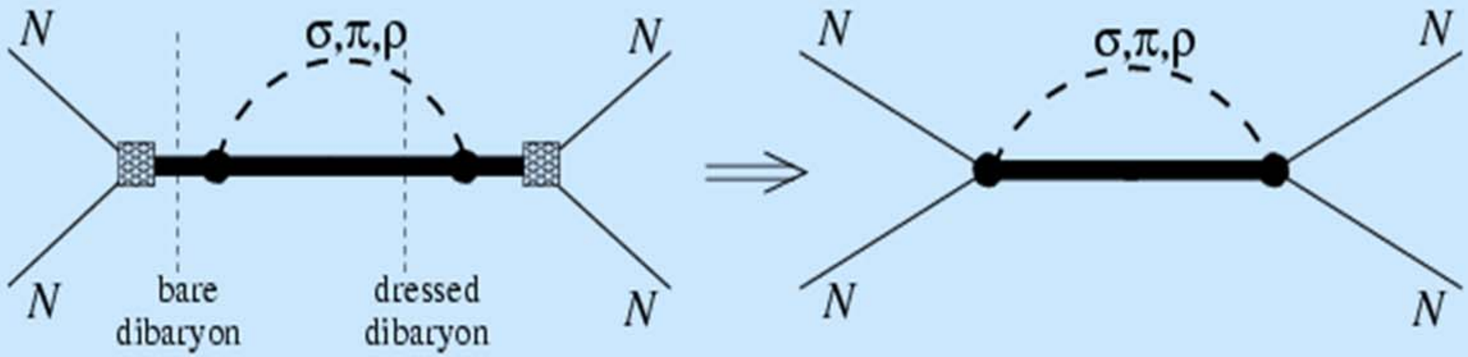
The effects of strong σ-field around six-quark bag.

This strong σ-field leads to highly non-linear effects:
— *(partial) restoration of chiral symmetry in the dressed bag;*
— *shrinking the multi-quark bag due to strong 'pressure' of scalar field;*
— *enhancement of scalar diquark correlations in the bag.*



The σ-field has mainly spherical symmetry due to $L_\sigma = 0$ and high space symmetry ($s^6[6]L_q = 0$) of the bag, and thus the field pulls quarks to the center of the bag and results in effective strong attraction among all the six quarks in the bag in this dressed bag state (DBS). As a net result of this inter-quark effective attraction there arises a strong attraction between two nucleons in NN-channel.

II. The concept of NN interaction based on intermediate dressed dibarion production



The σ-dressing of intermediate dibaryon shifts its mass downward noticeably ($\Delta \sim 0.5 - 0.7$ GeV).

The similar σ-dressing of the Roper resonance:

$$|s^2(2s)[3]\rangle \Rightarrow |s^3[3] + \sigma\rangle$$

reduces its mass about 0.5 GeV!

The effective potential V_{NqN} induced by coupling the NN-channel to the intermediate-dibaryon channel in form of a sum over simple separable terms for each partial wave:

$$V_{NqN} = \sum_{S,J,L,L'} V_{LL'}^{SJ}(\mathrm{r}, \mathrm{r}'), \tag{15}$$

with

$$V_{LL'}^{SJ}(\mathrm{r}, \mathrm{r}') = \sum_{M} Z_{LS}^{JM}(\mathrm{r})\, \lambda_{SLL'}^{J}(E)\, Z_{L'S}^{JM*}(\mathrm{r}'), \tag{16}$$

where $Z_{LS}^{JM}(\mathrm{r})$ are the potential form factors (vertex)

$$Z_{LS}^{JM}(\mathrm{r}) = \zeta_{LS}^{J}(r)\, \mathcal{Y}_{LS}^{JM}(\hat{\mathrm{r}}) \tag{17}$$

and the energy-dependent coupling constants $\lambda_{SLL'}^{J}(E)$ are expressed by integration of the product of two transition vertices B and convolution of the product of meson and quark-bag propagators over the momentum k:

$$\lambda_{SLL'}^{J}(E) = \sum_{L_\sigma} \int_0^\infty k^2\, dk \frac{B_{L_\sigma LS}^{J}(k, E)\, {B_{L_\sigma L'S}^{J}}^{*}(k, E)}{E - m_{d_0} - \frac{k^2}{2m_{d_0}} - \omega_\sigma(k)}. \tag{18}$$

The phase shifts of NN scattering in low partial waves

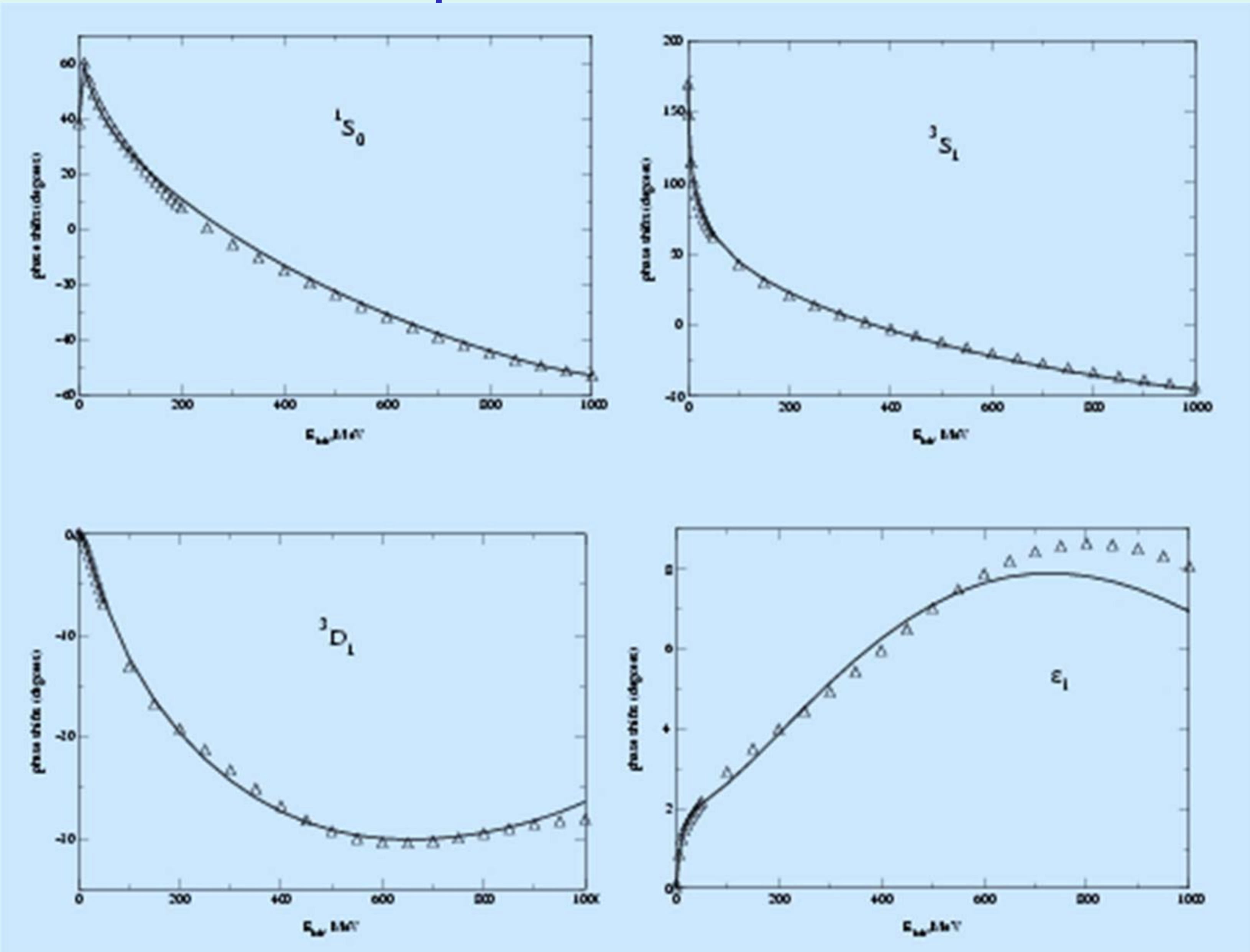


Table 1. Deuteron properties in the dressed bag model.

Model	E_d(MeV)	P_D(%)	r_m(fm)	Q_d(fm^2)	$\mu_d\,(\mu_N)$	A_S(fm$^{-1/2}$)	$\eta(D/S)$
RSC	2.22461	6.47	1.957	0.2796	0.8429	0.8776	0.0262
Moscow 99	2.22452	5.52	1.966	0.2722	0.8483	0.8844	0.0255
Bonn 2001	2.224575	4.85	1.966	0.270	0.8521	0.8846	0.0256
DBM (1) $P_{\rm in} = 3.66\%$	2.22454	5.22	1.9715	0.2754	0.8548	0.8864	0.0259
DBM (2) $P_{\rm in} = 2.5\%$	2.22459	5.31	1.970	0.2768	0.8538	0.8866	0.0263
experiment	2.224575		1.971	0.2859	0.8574	0.8846	0.0263

The σ-content of the nucleon and Roper resonance.

L. Kisslinger et al. suggested a hybrid model (within a gluonic hadron picture) for the σ-meson (L.S. Kisslinger, J. Gardner and C. Vanderstraeten, Phys. Lett. **B 410** (1997) 1).

Then S. Naryson (Nucl. Phys. B **509** (1998) 312) and L. Kisslinger (Phys. Lett. **B445** (1999) 271) used QCD sum rules for glueballs and mixed meson-glueball hadrons.

As a result it was found:

Basic findings of Kisslinger's et al work

1. The low-mass scalar glueball can be understood as coupled-channel glueball/sigma in the region below 1 GeV, with σ being a two-pion phenomenon (by the σ we mean the enhancement in the π-π I=0, L=0 amplitude).
2. From analysis of glueball decays and π-π phase shifts one can extract the gluon-sigma coupling strength to predict 2π-decay of hybrids.

   "It was proposed that the physical origin of the σ enhancement is the light scalar gluonic mode."

(The strong coupling to 2π-continuum might be a good explanation for the absence of light narrow glueball in lattice gauge calculation.)

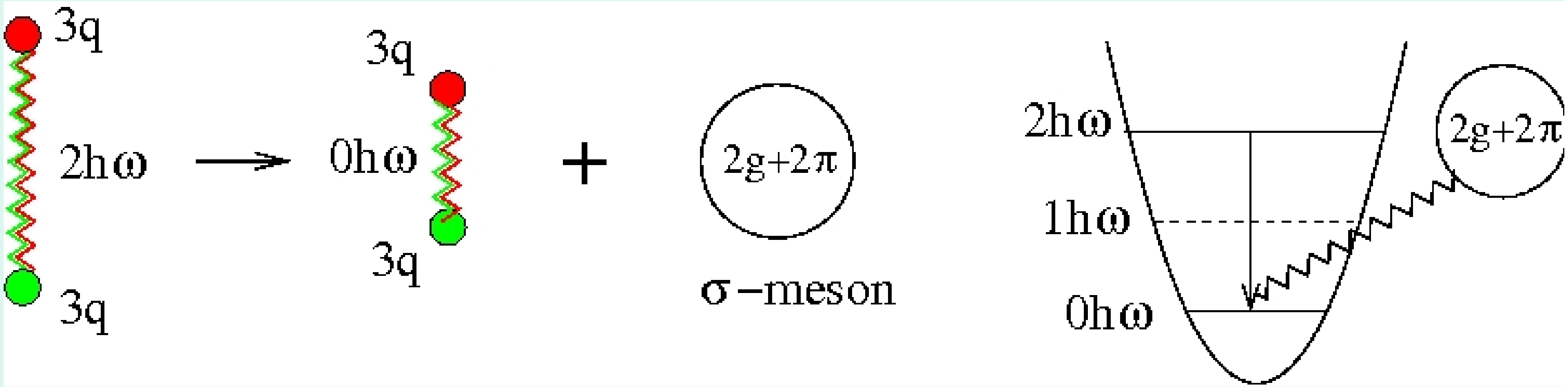
The QCD sum rules consideration for hybrid current in nucleon and Roper resonance has demonstrated that:

- The nucleon has a very small hybrid component, while for the Roper the purely hybrid current give a noticeable contribution (see e.g . L.S. Kisslinger and Z. Li, Phys.Lett. B **445** (1999) 271). So, they predicted a dominating σ+N decay mode for the Roper.

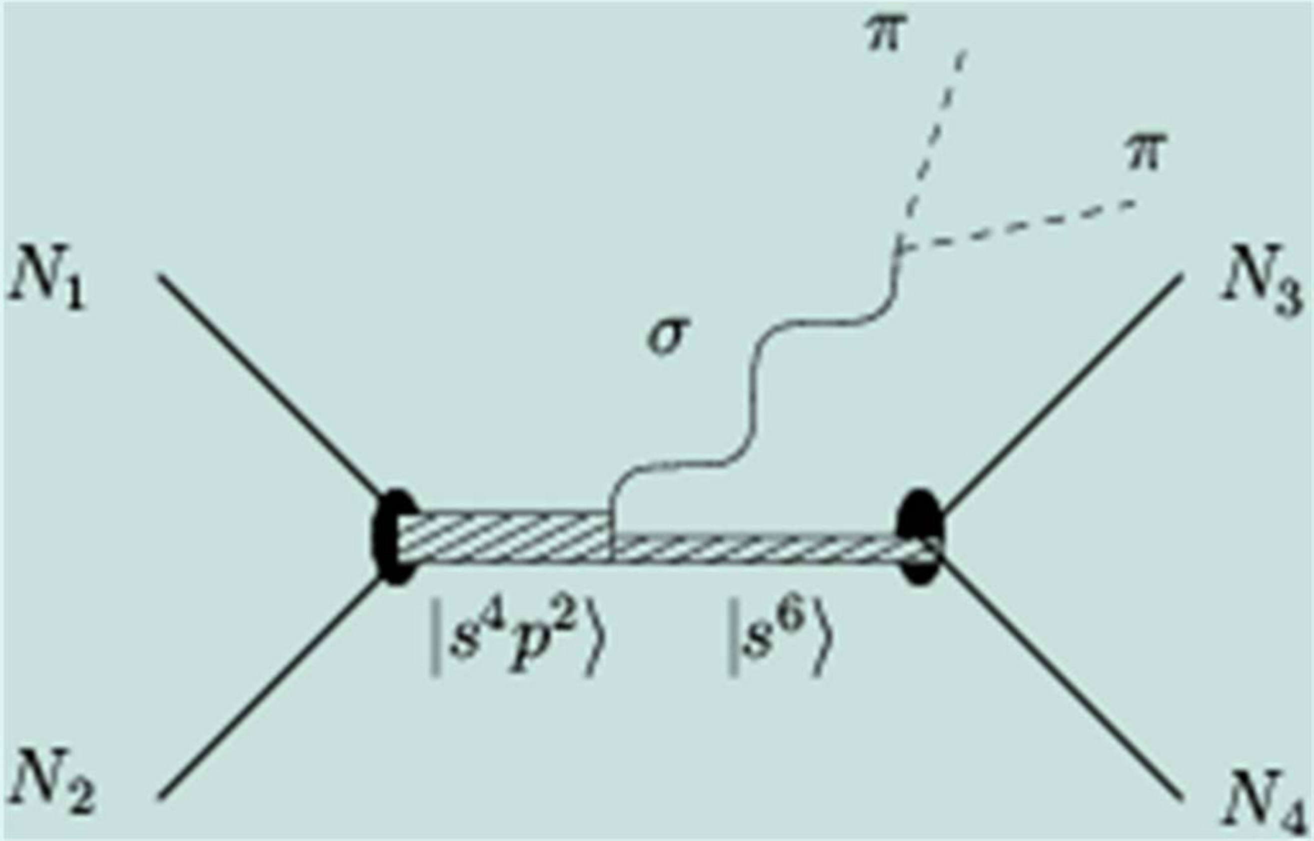
- The direct experimental data (of H. Clement et al. and many others) suggest that the width of Roper resonance decaying into sigma+N final states is generally an order of magnitude larger than those of other resonances.

Interpretation in terms of the $2\hbar\omega$-excited string.

See A. Faessler, V.I. Kukulin and M.A.Shikhalev, Ann. Phys. **320** (2005) 71.



The dibaryon model prediction for the two-pion production via σ-meson at p+n or p+p collisions



$\pi\pi$ Production in Nuclei

- medium effects of the $\pi\pi$ system

- nuclei as isospin filter:

$\pi^0\pi^0$ – system

  – $pp \longrightarrow pp\ \pi\pi$ $\qquad I = 0, \cancel{1}, 2$

  – $pn \longrightarrow d\ \pi\pi$ $\qquad 0, \cancel{1}$
  – $pd \longrightarrow {}^3He\ \pi\pi$: $\qquad 0, \cancel{1}$
  – $dd \longrightarrow {}^4He\ \pi\pi$: $\qquad 0$

$\left.\begin{array}{l} \\ \\ \\ \end{array}\right\}$ **ABC effect**

ABC effect

(**A**bashian, **B**oth, **C**rowe)

Inclusive measurements:

pd $\longrightarrow$ ^{3}He X

Abashian et al. Berkeley

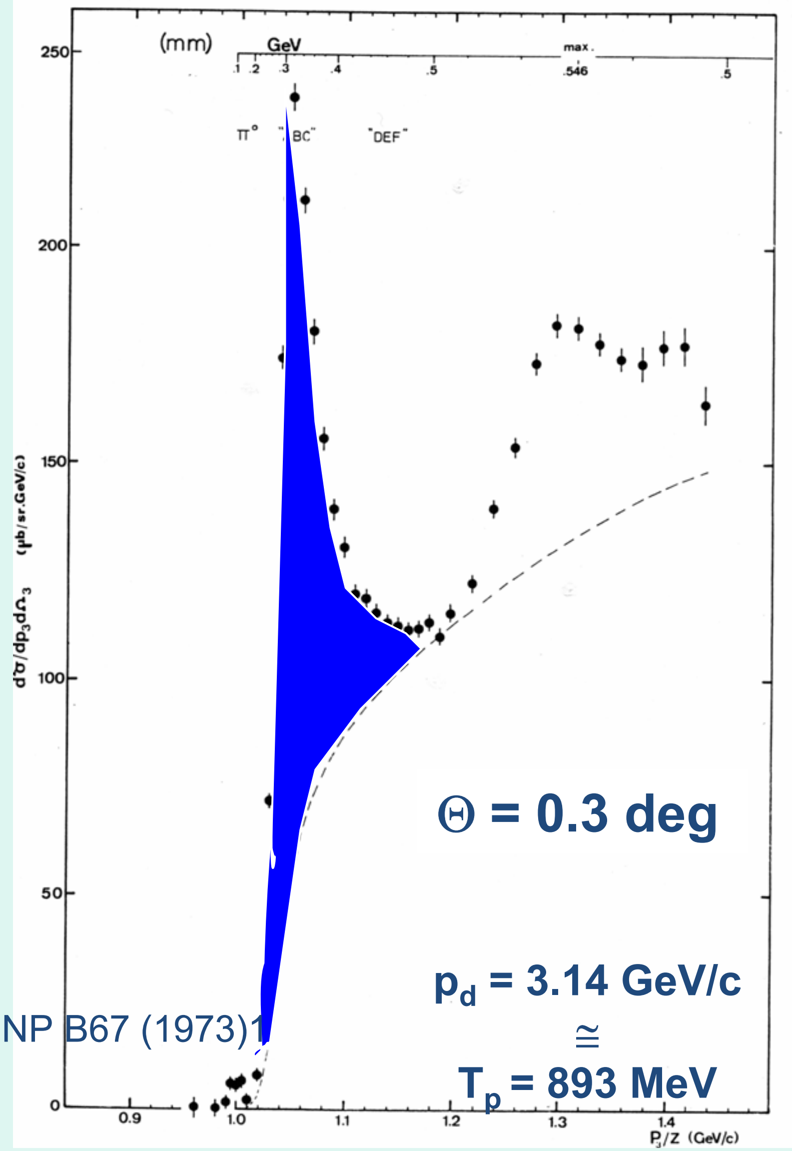
Banaigs et al. Saclay

$\Rightarrow$

low-mass enhancement !

Missing mass [GeV/c^2]

.3 .4 .5 $\rightarrow$



NP B67 (1973)1

First exclusive measurement: @ CELSIUS-WASA

$p\, d \rightarrow {}^3He\ \pi\pi$ @ T_p = 895 MeV

$M_{\pi\pi}$ $M_{^3He\ \pi}$

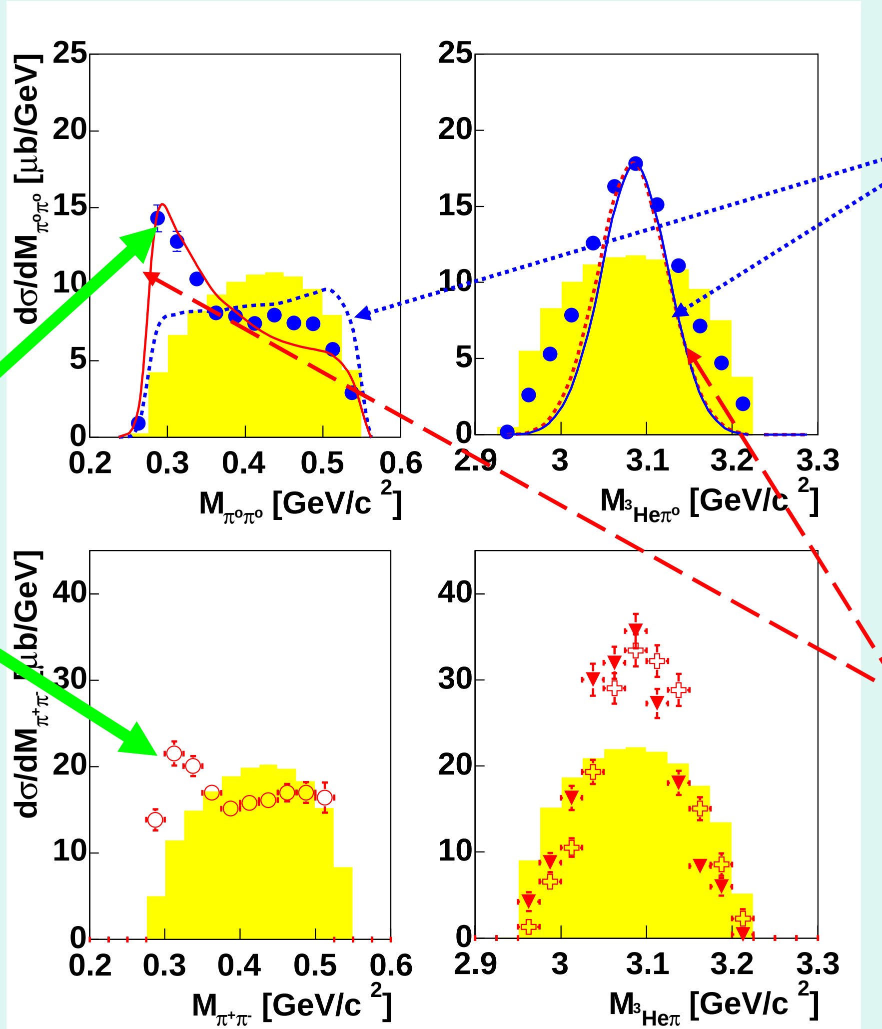
$\pi^0\pi^0$

(I = 0)

ABC

$\pi^+\pi^-$

(I = 0, 1)



$(\Delta\Delta)_{conventiona}$

$(\Delta\Delta)_{int}$

Phys. Lett. B637, 223 (2006)

Conclusions

1. The deficiency of scalar fields in OBE- and constituent quark models gives a very strong evidence in favour of existence of σ-dressed intermediate dibaryons in which the scalar field is generated in the string deexcitation process.
2. The similar mechanism for the scalar field generation is producing a large mass shift of the Roper resonance and leads to dominating N+σ channel in the Roper decay. (This conclusion is in a full agreement with QCD sum-rule solution of Kisslinger et al. and the Clement's et al experiments.)
3. The dibaryon model for nuclear force leads to numerous implications for nuclear physics – main of them is an appearance of a new non-nucleonic (i.e. the dressed dibaryon) components in nuclear wave functions with probability ≥10%. In turn, these new components leads to new e.-m. currents, new powerful 3N force, existence of cumulative processes in hadronic scattering off nuclei, etc.