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INTERNAL REPORT
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TOPICAL MEETING

ON ELECTROMAGNETIC AND WEAK INTERACTIONS IN NUCLEI

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(SUMMARIES AND CONTRIBUTIONS)

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EXCHANGE EFFECTS AND RELATED TOPICS

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1. The Charge Form Factor (C.F.F.) of He^3

The He^3 calculations[1,2] with the best nuclear wavefunctions derived from the Reid soft core potential are now in better agreement with each other. The result in ref. 1 contained a numerical error and the corrected values are now consistent with ref. 2 i.e. a minimum at $q^2 \approx 14\ fm^{-2}$ with a secondary maximum of $\approx 1.5 \times 10^{-3}$ at $q^2 \approx 19\ fm^{-2}$ for wavefunctions derived from the $^1S_0$, $^3S_1 - {}^3D_1$ Reid potential. This still leaves the theoretical estimate about a factor of three below the experimental value at the secondary maximum.

There have been several calculations of "exchange current" corrections to these purely nuclear results. The pair effect[3] shown in fig 1 gives a large helpful correction at the secondary maximum but spoils the fit at $q^2 \approx 8\ fm^{-2}$ by pushing the theoretical C.F.F. about 30 % below the experimental value. The result of ref. 3 has

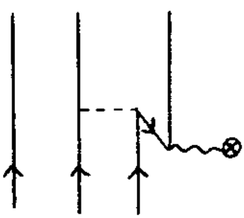


Fig. 1

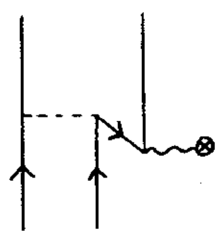


Fig. 2

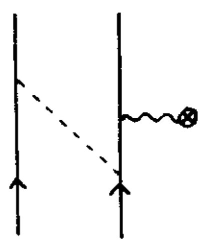


Fig. 3

been viewed with some scepticism and has yet to be completely checked. However, a partial justification of their result has been given in ref. 4. They consider the analogous case for the deuteron (fig. 2) and show that this is partially cancelled by the recoil and renormalisation contributions of fig. 3. Even so the remaining effect is still substantial.

Another correction[5)] (fig. 4) makes things worse everywhere. At the secondary maximum it is small and even goes in the wrong direction, and at $q^2 = 8\ fm^{-2}$ it spoils the pure nuclear fit by raising the theoretical estimate by about 30 % above the experimental value.

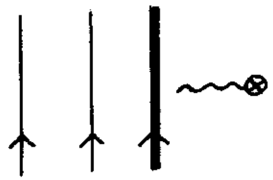


Fig. 4

Fig. 5

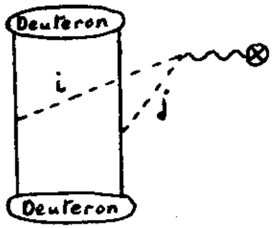
Presumably the combined results of refs. 3 and 5 would give a reasonable fit for q^2 upto about 20 fm^{-2}.

However, this is not the end of the story. The process shown in fig. 5 "said" to be zero in ref. 5 has been estimated[6)] by Ho-Kim and Kisslinger and they indeed find the effect to be small. However, Kloet and Tjon[7)] find it to be large - comparable to their pair effect! To make matters worse Ho-Kim and Kisslinger[6)] find that when the Δ(1236) is replaced in fig. 5 by the N^*(1688) they also get a large effect. In ref.15 the processes shown in fig. 6 have been estimated for the deuteron, but they find that their total contribution is small for $q^2 < 20\ fm^{-2}$.

The conclusion is that for $q^2 \gtrsim 10\ fm^{-2}$ exchange current effects are needed. Also there seems to be more than sufficient processes that can contribute significantly; but, at present, there is disagreement amongst theorists as to their evaluation.

2. The Δ(1236) in nuclear matter

Most of the results of this section can be found in ref. 8. The main conclusion is that, when the Δ(1236) is introduced explicitly into the two nucleon interaction there arises in nuclear matter a repulsive contribution to the binding energy of about 5 MeV per particle at $k_F = 1.4\ fm^{-1}$. This contribution increases approximately as the square of the density ($0.7\ k_F^6$) and is found using both the Pandharipande and Brueckner approaches. Ben Day has apparently found a similar result[9)]. It is also shown that this repulsion is counteracted by three-body forces as recently calculated in ref. 10. Their combined effect is found to give a mechanism for moving in the desired direction away from the Coester line. However, a comment in ref. 11 says that the effect of the ϕ^3 term in the Lee-Wick Langrangian used for studying abnormal states of matter can give rise to a 3-body attraction (fig. 7) amounting to about 30 % of the two-body attraction i.e. an additional 10 MeV per particle. Fortunately the authors add that this is presumably reduced by nuclear correlations. This same problem is also being studied by Rho and Nyman



$[i,j] = [\pi,\rho]$ and $[\sigma,\omega]$

Fig. 6

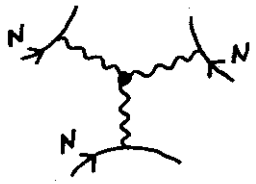


Fig. 7

at Saclay (private communication from B.H.J. McKellar) and they find that this 3-body effect is very dependent on various adjustable parameters in the Lee-Wick game.

The conclusion is that the combination of Δ's and 3-body forces gives the desirable effect of pushing nuclear matter saturation to lower densities without reducing the binding energy per particle. However, this picture may be all upset by the Lee-Wick ϕ-meson.

3. $P + P \to D + \pi^+$

An alternative way for calculating pion production in nucleon-nucleon scattering is proposed[12]. As a test the β-parameter for p-wave pion production in $p + p \to d + \pi^+$ is calculated from the processes shown in figs. 8. ($\sigma(\text{prod.}) = \alpha q + \beta q^3$) In this approach we concentrate on maintaining the correlation

between pp and between NΔ as dictated by <u>elastic</u> pp scattering.

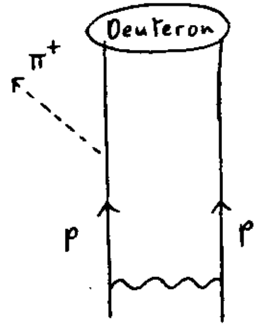


Fig. 8a

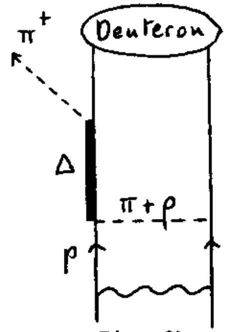


Fig. 8b

In other approaches the emphasis is on ensuring the πN scattering amplitude in fig. 8b is correct.

The parameter β is expressed as

$$\beta = \frac{5.1 \times 10^3}{[T(Lab)]^{3/2}} |M|^2$$

where $M = \langle \Psi_d | \sum_{i=1,2} \sigma_i \cdot \nabla_\pi | \Psi_I \rangle$. Here $\Psi_I = a\Psi(PP) + b\Psi(N\Delta)$ is the combination of proton-proton and nucleon-Δ(1236) wavefunctions needed to fit two-nucleon <u>elastic</u> scattering when the two nucleon hamiltonian contains the inelastic interaction $\langle NN|V|N\Delta\rangle$. The deuteron is considered to be simply a neutron and a proton. The operator "σ_i" represents not only the usual Pauli spin operator but also the transition operator between a nucleon and a Δ. The π-emission operator has not been made Galilean-invariant[13]. Writing $|M|^2 = (A + B)^2 + 2(C + D + E)^2$ we get the results shown in the table which are in reasonable agreement with experiment ($\beta \sim 0.7 - 1.0$). In comparison with other approaches (see ref. 14) we believe our method does less "double-counting". Also we find that ρ-meson exchange is important in ψ_I.

		A	B	C	D	E	β
Initial State		^1S_o	^5D_o	$^1D_2$	$^5S_2$	$^5D_2$	
Final State		$^3S_1$	$^3D_1$	$^3D_1$	$^3S_1$	$^3D_1$	
T_{Lab}(MeV)	304	-.002	.030	.125	.124	-.019	1.02
	352	+.003	.028	.121	.138	-.020	.89

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