Bubble at the core of He^4 and the 770MeV $He^4(p,d)$ reaction

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There has been some helplessness felt while analyzing (p,d) reaction data at energies aroung 700 to 800 MeV[1–7]. The situation is worst with the analysis of $770 MeV He^4(p,d)He^3$ reaction [3]. The Plane Wave (PW) as well as the Distorted Wave Born Approximation (DWBA)analyses of this data indicated much sharper angular distributionsthan what the data shows. Varying distorting potentials as well as incorporating correlations of the Jastrow type did not result in any significant improvement[3]. We tookup the challenging task to understand this data from the point of view of incorporating ths short range nucleon-nucleon (N-N)pairing interactionin the wave function of the pickedup neutron.

We started with the 4-nucleon shell model harmonic oscillator wave function for He^4 and then using Brody Moshinsky transformation [8] expressed this wave function as a function of the relative coordinates of two protons and two neutrons beside their centre of mass motion wave functions. Now the relative N-N wave function should infact be the solution of the Schroedinger equation incorporating the N-N short range residual (pairing) interaction beside the longer range single particle motion interaction. Therefore for the N-N radial wave function we solved a bound state Schroedinger equation incorporating a Woods Saxon potential along with the v_{14} Argonne N-N interaction[9] for the neutron-neutron, $(n$-$n)$ T=1, S=0 ald L=0 state. Solutions of these paired n-n and p-p relative motion are thus replaced in place of the shell model relative wave functions. Next we used the Fourier Transform techniques to

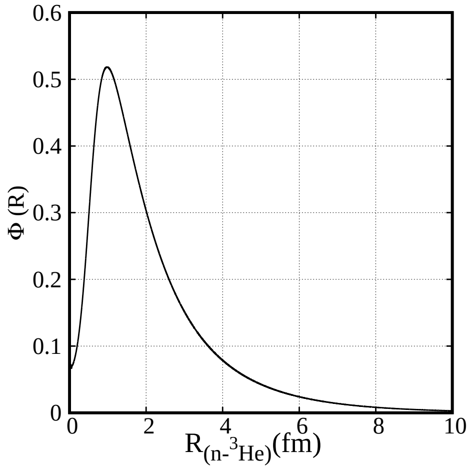

FIG. 1: n-He^3 Wave function $\Phi_{n\tau}(R_{n\tau})$

correct for the fictitiois centre of mass motion.The plane wave transition matrix element for the $He^4(p,d)He^3$ reactioncan be immediately written as:

$$T_{fi} = B \int exp\{i(\vec{k_p} - \vec{k_d}/2)\cdot\vec{r}_{pn}\}\phi_d(\vec{r}_{pn})d\vec{r}_{pn} \times \int exp\{i(3\vec{k_p}/4 - \vec{k_d})\cdot\vec{R}_{n\tau}\}\Phi_{n\tau}(\vec{R}_{n\tau})d\vec{R}_{n\tau}$$

Here we have used the same first integral $D_L(\Delta)$ as in Ref.[4] which uses the Reid soft core interaction [10] and where the L=2, d-state contribution is dominant. For the $\Phi_{n\tau}(r_{n\tau})$ we used the above mentioned procedure which produces the s-state wave function using the Argone v_{14} interaction [9] for the short range part along with a longer range Woods Saxon potential. This wave function is represented in Fig.1. The Fourier transform of this wave function is seen in Fig.2. The angular distribution using these ingradients is seen in Fig.3.

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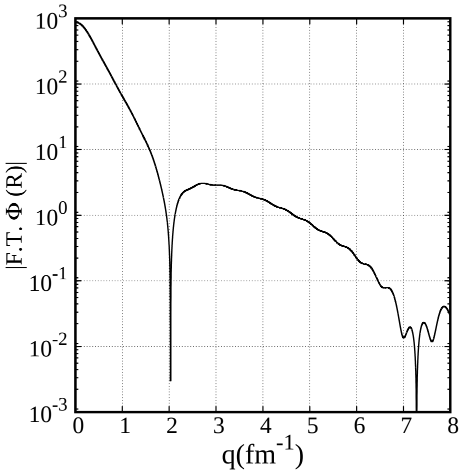

FIG. 2: Fourier Transform of $\Phi_{n\tau}(R_{n\tau})$

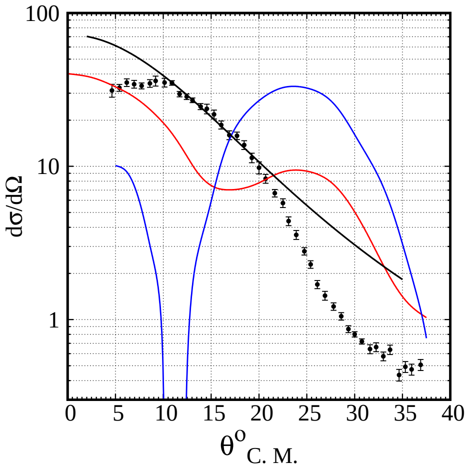

FIG. 3: Our PW calculations (black line) compared with that of Rost et al[3](PW blue line and DW red line) and with the data[1]

Now one can see that while there are huge differences between the PW and DWBA calculations of Rost et al [3] with the data because there are too few large momentum components in their wave functions as compared to enhanced large momentum components in our Fig.2. On the other hand our PW calculations fit the data much better except for some differences at small angles and similar small difference at large angles. These small differences probably can be understood in terms of a proper evaluation of the $D_L(\Delta)$ term which uses only a simplified evaluation using Reid Soft core potential for the deuteron neglecting the coupling Tensor term. One can easily witness in Fig.1 that these short range residual interactions produce a large dent in $\Phi_{n\tau}(R_{n-He^4})$ around $R < 0.7fm$ corresponding to a bubble at the core of He^4. Another point to be noted is that one can improve our calculations using the p-n correlations which will correspond to the triplet S=1-state interaction containing the D-state through the large contribution from the Tensor interaction. The D-state produces a peak at larger angles than that from the S-state, besides ofcourse some small contributions from the optical distortions.

In conclusion one can say that we have achieved a major break through where the large momentum components in nuclear single particle wave functions are produced by the Short Range residual interaction which effectively represents the n-n-pairing interaction and produces a bubble at the core of the nucleus.

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