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Research article

Diprotons, singlet deuterons, dineutrons.

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Abstract.

Diproton and dineutron emission has been observed recently. Fifty years ago Bilaniuk and Slobodrian reported experimental results on the reaction $^3He\ (^2H,^3H)^2He$. The observed tritons (^3H) via magnetic analysis revealed a broad peak and allowed to assign a lifetime to ^2He or diproton. It is a member of the i-spin triplet: pp,np,nn.Their strong nuclear interaction near zero energy is a singularity. Unclear comments and interpretations on the dinucleons, given at conferences and publications need clarification, given below.

Keywords : dinucleons, diproton, dineutron, i-spin

Introduction.

Reactions with the emission of diprotons and dineutrons have been published recently [1,2]. Early evidence for the diproton was obtained via the reaction $^3He\ (^2H,^3H)^2He$ [3] with the 28 MeV incident deuteron beam facility of the Buenos Aires synchrocyclotron [4] . Evidence for the dineutron was acquired by the reaction $^3H(^2H,\ ^3He)^2n$ [5] with the deuteron beam of the Berkeley AVF cyclotron [6]. The experiments were carried out with tritium gas targets which required paramount precautions, due to the risk of contamination of the machine in the event of a leak, turning it inoperable due to the high costs of its maintenance beyond budgetary limits. Considerations on the relevant physical conditions of these reactions yielding asymptotically three bodies and dominated by two body final state interactions, are available in Refs.7, 8, 9. Dineutron emission has been observed and discussed in detail by Spyrou & al [10]. A theoretical discussion on dineutrons is due to Kirk T. McDonald [11], available on the internet.

The dinucleon states.

There are four dinucleon states: The deuteron (bound state) and the unbound pp, nn and np pairs, the latter referred often as the singlet deuteron, the two former ones, as diproton and dineutron respectively. No direct neutron-neutron scattering has yet been attempted. Evidence on the neutron-neutron interaction is thus based on transitions leading to nn systems in the final state.The experimentally observed peaks due to dinucleons have been understood as singularities of the S-matrix [12], and classified as virtual or antibound states: at negative energy on the unphysical sheet of the Riemann surface associated with the complex energy plane [13]. Virtual states and Breit Wigner (BW) resonances (at complex energy values) are not stationary or true quantum mechanical states. Their wave function is not square integrable in the Lebesgue sense and thus it is non normalizable. The Appendix shows ambiguity in the character of dinucleon singularities near zero energy.

Concluding remarks.

Dinucleons are now accepted as nuclear subunits. The broad peaks Identified with them in final state interactions can be associated with virtual states or with BW resonances in representations based on two parameters [7] (Appendix). BW resonances near zero energy and large width do not have a Lorentzian symmetric shape [14,15], they are asymmetric and resemble the peaks of virtual sates near zero energy. Neutron-neutron scattering parameters could be determined experimen-tally via intense neutron-neutron beam collisions and bring closure a long standing ignorance and controversy over fundamental nucleonic force interaction parameters, in particular, at the n-n low energy range, relevant for atomic nuclei.

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APPENDIX.

Breit Wigner resonance or virtual (antibound) state.

The dinucleons (pp,np.nn) are on an S state. For simplicity we consider the nn dinucleon.

The scattering partial wave amplitude for S-waves is:

$$|f|^2 = \frac{\sin^2 \delta}{k^2} = \frac{1}{k^2\,(1+\cot^2 \delta)}$$

The low energy expansion of the denominator yields for the denominator in terms of the scattering length a and the effective range r_e

$$k^2\,(1+\cot^2 \delta) = (1/a)^2 + (1- r_e /a)k^2 + \ldots s$$

The Breit Wigner of

$$\cot^2 \delta = \frac{4\,[(k^2 / 2\mu) - (r_e^2 /2\mu)]}{\Gamma^2}$$

Γ^2 is not a constant: $\Gamma^2 \cong (\,ka\,)^2$ and finally

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$$k^2 \cot^2 \delta = 1/\alpha^2 (k^2/2\mu - r_e{}^2/2\mu)$$

A proper choice of α and r_e would allow a representation as a Breit Wigner resonance or as a virtual state near zero energy. They are equivalent two parameter representations of the experimental cross sections. Moreover, the p-p hard sphere corrected $1S_0$ phase shift increases beyond 90^o and a Breit Wigner representation is also warranted.