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LETTER TO THE EDITOR

A local $^1S_0$ proton-proton potential

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Abstract. A local $^1S_0$ p–p potential is introduced. This potential has an interesting shape and gives phase shifts for p–p scattering which are in very good agreement with the experimental phase shifts.

In a recent letter (Kermode 1972) the first stage of work to find local potentials to reproduce the experimental phase shifts, within experimental error, for each angular momentum and isospin nucleon–nucleon state was reported. That letter was concerned with the $^1S_0$ neutron–proton potential.

The present letter introduces an equivalent local interaction between one proton and another in a relative $^1S_0$ state. It was hoped that the determination of this local interaction would complete the second stage of the current program. However, the shape of the potential, in that it has a second minimum, is quite different from, for example, the shape of the Reid potentials (Reid 1968) and it will now be necessary to

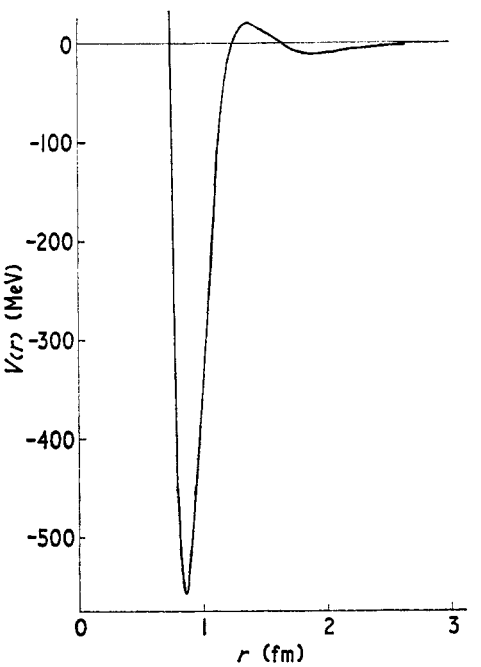

Figure 1. A local $^1S_0$ proton–proton potential.

find whether or not there are other equivalent local potentials which fit the experimental data to such a high degree of accuracy.

The potential, which is shown in figure 1, has the Yukawa expansion

$$V(r) = -r^{-1} \sum_{n=1}^{12} A(n)\mathrm{e}^{-n\mu r},$$

where r is the distance between the protons, $\mu = 0{\cdot}7\ \mathrm{fm}^{-1}$ and the values of $A(n)$ are given in table 1. For computational convenience the potential is taken to be zero for r greater than 12 fm.

Table 1.

n	$A(n)$ (MeV fm)	$A(n+1)$ (MeV fm)	$A(n+2)$ (MeV fm)
1	1494700×10^{-5}	7476735×10^{-4}	-1657004×10^{-2}
4	7548636×10^{-2}	8611086×10^{-2}	2894022×10^{-1}
7	-5171313×10^{0}	-1138254×10^{1}	1286216×10^{2}
10	-2913635×10^{2}	2654373×10^{2}	-8657677×10^{1}

This potential gives phase shifts which are in excellent agreement with the $^1S_0$ p–p phase shifts of MacGregor *et al* (1969), the largest deviation being 0·04° at 300 MeV(lab). (The Reid potential gives a good fit to the phase shifts but not to within experimental error at all energies.) Vacuum polarization effects were taken into account using the recipe of Kermode and Sprung (1969) and the recipe verified when the potential had been obtained.

The potential was found using the CDC 7600 computer at the Manchester Regional Computing Centre with an accuracy of 14 significant figures. For the Liverpool University ICL KDF9 computer with an accuracy of 11 significant figures it was found that the very small rounding off errors could be compensated for by changing $A(2)$ from 747·6735 to 747·7735, with negligible effect on the shape of $V(r)$.

It may or may not be possible to find other shapes for the potential which produce an equally good fit to the experimental phase shifts. This is now under investigation. Also the actual interaction between protons almost certainly contains nonlocal terms and the present potential should serve as a useful starting point for the gradual introduction of nonlocal terms while maintaining the fit to the phase-shift data. Other calculations, the three-body problem for example, will then be necessary to select a representation of the actual interaction.

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