Modified separable representation of the Paris nucleon-nucleon potential in the $^1S_0$ and $^3P_0$ states

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We give a modified separable representation of the Paris potential, which is to remedy shortcomings of an earlier parametrization in the $^1S_0$ and $^3P_0$ partial waves. In particular, the present parametrization does not lead to the unphysical bound states at very large negative energies as encountered previously. Still, it provides for a good approximation of the on-shell as well as off-shell properties of the Paris potential.

In Ref. 1 we constructed a separable representation of the Paris nucleon-nucleon (N-N) potential[2] by means of the Ernst-Shakin-Thaler (EST) method.[3] It consisted of an adequate approximation of the on-shell as well as off-shell behavior of the Paris N-N interaction model. In the meantime these so-called PEST (Paris EST) potentials[1] have become of great use in introducing the features of advanced meson-exchange theory[4] into calculations of few-body systems like, e.g., of the ^{3}H bound state[5] or of nucleon-deuteron (N-d) scattering.[6–8]

Unfortunately, we overlooked a shortcoming in the PEST3 and PEST2 separable parametrizations of the $^1S_0$ and $^3P_0$ partial waves. In particular, they produced unphysical bound states at very large negative energies ($E \lesssim -600$ MeV). The associated poles in the N-N transition operator would in principle enter into few-body calculations at least in a Faddeev-type integral equation approach. In practice, however, we have not observed any noticeable influence on three-nucleon bound-state or scattering results coming from these poles so far out at negative energies. Still, it is necessary to avoid them in order to ensure a true reproduction of the Paris potential properties. We remedy the earlier defect by the following improved parametrizations.

For $^1S_0$ we used as interpolation energies ($E = 0$, 100, 500 MeV), whereas for $^3P_0$ the energies ($E = 50$, 350 MeV) were selected. Thereby, we make any unphysical poles disappear in both states. The separable form factors are the same as before, only the parameters have to be changed to the new ones given in the present paper. For $^1S_0$ the new parameters in Table I are to replace the ones quoted for PEST3 in Table II of Ref. 1, while for $^3P_0$ Table II gives the new values to be used for PEST2 instead of the corresponding parameters quoted in Table IV of Ref. 1.

The new PEST3 and PEST2 potentials have practically the same on-shell as well as off-shell behavior as before. Evidently, PEST3 has the same low-energy behavior as given in Table III of Ref. 1, but also with respect to the other properties it conforms to what is shown there in Figs. 1–4. The

TABLE I. Parameters of the PEST3 potentials in the $^1S_0$ partial wave (to replace Table II of Ref. 1). With respect to the n-p case, which is not contained in the original Paris potential, see the discussion in Sec. III A of Ref. 1.

	p-p			n-p	
β (fm^{-1})	C (fm^0)	λ (MeV fm^{-1})	β (fm^{-1})	C (fm^0)	λ (MeV fm^{-1})
$\beta_{11}=1.1115753$	$C_{11}=-572.2923$	$\lambda_{11}=-0.0008641213$	$\beta_{11}=1.1115753$	$C_{11}=-773.80000$	$\lambda_{11}=-0.0004644316$
$\beta_{12}=2.021232$	$C_{12}=-313.6236$	$\lambda_{12}=0.013605055$	$\beta_{12}=2.021232$	$C_{12}=-424.05244$	$\lambda_{12}=0.0098132185$
$\beta_{13}=2.6434278$	$C_{13}=12814.143$	$\lambda_{13}=0.0022668576$	$\beta_{13}=2.6434278$	$C_{13}=17326.082$	$\lambda_{13}=0.0012041892$
$\beta_{14}=4.0877911$	$C_{14}=-28477.672$	$\lambda_{22}=-0.24728686$	$\beta_{14}=4.0877911$	$C_{14}=-38504.839$	$\lambda_{22}=-0.24043231$
$\beta_{21}=1.0297944$	$C_{21}=-18.494719$	$\lambda_{23}=-0.14688383$	$\beta_{21}=1.0297944$	$C_{21}=-18.494719$	$\lambda_{23}=-0.1366375$
$\beta_{22}=1.5435994$	$C_{22}=-53.628348$	$\lambda_{33}=0.67052284$	$\beta_{22}=1.5435994$	$C_{22}=-53.628348$	$\lambda_{33}=0.67334726$
$\beta_{23}=2.6129194$	$C_{23}=925.42408$	$\lambda_{ij}=\lambda_{ji}$	$\beta_{23}=2.6129194$	$C_{23}=925.42408$	$\lambda_{ij}=\lambda_{ji}$
$\beta_{24}=4.0837929$	$C_{24}=-2040.002$		$\beta_{24}=4.0837929$	$C_{24}=-2040.002$	
$\beta_{31}=1.0416637$	$C_{31}=1.2361845$		$\beta_{31}=1.0416637$	$C_{31}=1.2361845$	
$\beta_{32}=1.8741794$	$C_{32}=9.4601176$		$\beta_{32}=1.8741794$	$C_{32}=9.4601176$	
$\beta_{33}=3.0550142$	$C_{33}=646.74738$		$\beta_{33}=3.0550142$	$C_{33}=646.74738$	
$\beta_{34}=3.847925$	$C_{34}=-1031.2936$		$\beta_{34}=3.847925$	$C_{34}=-1031.2936$	

TABLE II. Parameters of the PEST2 potential in the $^3P_0$ wave (to replace the parameters for PEST2 of $^3P_0$ in Table IV of Ref. 1).

β (fm^{-1})	C (fm^0)	λ (MeV fm^{-1})
$\beta_{11} = 1.869\,137\,9$	$C_{11} = -189.744\,07$	$\lambda_{11} = -0.116\,632\,53$
$\beta_{12} = 3.049\,986\,6$	$C_{12} = 2096.7281$	$\lambda_{12} = -0.014\,823\,51$
$\beta_{13} = 3.558\,575\,2$	$C_{13} = -3066.2694$	$\lambda_{22} = 3.204\,724\,5$
$\beta_{14} = 1.159\,629\,2$	$C_{14} = 102.753\,84$	$\lambda_{21} = \lambda_{12}$
$\beta_{21} = 2.516\,048\,1$	$C_{21} = 86.384\,083$	
$\beta_{22} = 3.006\,112$	$C_{22} = -1158.9099$	
$\beta_{23} = 3.179\,367$	$C_{23} = 8508.3848$	
$\beta_{24} = 3.385\,101\,8$	$C_{24} = -9858.2905$	

same is true for PEST2 in the $^3P_0$ state [Figs. 5 and 8(a) of Ref. 1].

The improved PEST potentials constructed here were already applied in the work of Ref. 8. Together with the parametrizations of the other N-N states as presented in Ref. 1 they should provide for a reliable representation of both the on-shell and off-shell properties of the Paris potential and allow them to be introduced into few-body and nuclear applications.

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