Bound, virtual and resonance S-matrix poles from the Schrödinger equation

A. M. Mukhamedzhanov , B. F. Irgaziev,[1] V. Z. Goldberg, Yu.V. Orlov,[2] and I. Qazi[1]
[1]*GIK Institute of Engineering Sciences and Technology,Topi, District Swabi, N.W.F.P.,Pakistan*
[2]*Skobeltsyn Institute of Nuclear Physics, Moscow State University, Russia*

A general method, which we call the potential S-matrix pole method, is developed for obtaining the S-matrix pole parameters for bound, virtual and resonant states based on numerical solutions of the Schrödinger equation. This method is well-known for bound states. In this work we generalize it for resonant and virtual states, although the corresponding solutions increase exponentially when $r \to \infty$. Concrete calculations are performed for the 1^+ ground state of ^{14}N, the resonance ^{15}F states ($1/2^+$,$5/2^+$), low-lying states of ^{11}Be and ^{11}N, and the subthreshold resonance in the proton-proton system. We also demonstrate that in the case of the broad resonances their energy and width can be found from the fitting of the experimental phase shifts using the analytical expression for the S-matrix. We compare the S-matrix pole and the R-matrix for broad resonances in the ^{14}*O-p* and in ^{26}*Mg-n*.

As example, in Table I we present the results of the calculations of the resonance states $½^{\pm}$ and $5/2^+$ in ^{11}N. In the 6-th and 7-th columns are shown the calculated energies and single-particle proton partial resonance widths.

TABLE I. Energies and widths calculated for low-lying levels of ^{11}N by S-matrix pole method. The Coulomb radius r_C = 1.1 fm ($r_{ls} = r_0$, $a_{ls} = a$).

J	r_0 (fm)	a (fm)	V_0 (MeV)	V_{ls} (MeV)	E_{sp} (MeV)	Γ_{sp} (MeV)
$1/2^+$	1.20	0.753	57.057	0	1.014	0.843
	1.22	0.713	57.057	0	1.039	0.881
	1.25	0.650	57.057	0	1.081	0.944
	1.27	0.607	57.057	0	1.112	0.993
	1.29	0.562	57.057	0	1.146	1.048
$1/2^-$	1.20	0.819	37.505	6.0	1.919	0.944
	1.22	0.760	37.505	6.0	1.991	0.963
	1.25	0.650	37.505	6.0	2.134	0.996
	1.27	0.545	37.505	6.0	2.284	1.024
	1.28	0.451	37.505	6.0	2.426	1.047
$5/2^+$	1.20	0.753	57.057	7.13	3.672	0.959
	1.22	0.713	57.057	6.222	3.719	0.927
	1.25	0.650	57.057	4.743	3.793	0.878
	1.27	0.607	57.057	3.671	3.845	0.847
	1.29	0.562	57.057	2.520	3.900	0.8167