ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E-2440

I. Bystricky, F. Lehar, I. Ulehla

# NUCLEON-NUCLEON POTENTIAL WITH A SOFT CORE FOR THE $^1S_0$ STATE IN THE ENERGY REGION 0.17-310 MEV

ЛАБОРАТОРИЯ ЯДЕРНЫХ ПРОБЛЕМ
ЛАБОРАТОРИЯ ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

1965

E-2440

I. Bystricky, F. Lehar, I. Ulehla

# NUCLEON-NUCLEON POTENTIAL WITH A SOFT CORE FOR THE $^1S_0$ STATE IN THE ENERGY REGION 0.17-310 MEV

Submitted to Phys. Letters

In this paper it is attempted to describe the energy dependence of the $^1S_0$ phase shift $\delta_{^1S_0}$ in the NN system with the help of a potential with a soft core, given by

$$V_C(x) = (b_0 + b_1 e^{-x} + b_2 e^{-2x} \dots) \cdot e^{-x}/x \qquad (1)$$

where $b_i$ are coefficients and $x = \mu r (\mu = 0{,}707 \cdot 10^{13} cm^{-1})$.

The values of the phase shift $\delta_{^1S_0}$ obtained in /1/ were used in the region 20-310 MeV. Within the experimental errors these data are in good agreement with those of /2,3/.

It was assumed that below 20 MeV only the $^1S_0$ phase shift contributes simultaneously to the phase shift analysis and that the contribution of higher phase shifts is negligible. The quantity $\delta_{^1S_0}$ was determined in /4/ where data on the elastic $pp$ -scattering cross section were used. A good description of the phase shift $\delta_{^1S_0}(p,p)$ in the low-energy region is given by the scattering length $a_s(pp)$ and the effective radius $r_s(pp)$. The analogous quantities

$$a_s(n,p) = (23{,}680 \pm 0{,}028)\, 10^{-13} cm \quad \text{and} \quad r_s(n,p) = (2.46 \pm 0{,}13) \cdot 10^{-13} cm$$

were obtained from data on $np$ scattering. The scattering length $a_s(n,p)$ can be determined very precisely from $np$ -scattering at very low energies (of the order of several eV). The error in the determination of the effective radius is larger. We used these quantities to determine the phase shifts for $np$ -scattering below 20 MeV. It is well-known /4,5/ that the scattering lengths $a_s(pp)$ and $a_s(np)$ are different.

Taking the Coulomb interaction into account exactly we obtained the energy dependence of the $\delta_{^1S_0}(p,p)$ in the region 0.17-310 MeV satisfying the $\chi^2$ criterion.

The calculated $^1S_0$ phase shifts above 20 MeV for $np$ and $pp$ scattering coincide because they correspond to the phase shifts obtained as a result of the simultaneous phase shift analysis of pp and np data. When analysing the data the assumption that the Coulomb and nuclear phases are additive, is made.

It is impossible to describe the energy dependence of $\delta_{^1S_0}(pp)$ and $\delta_{^1S_0}(np)$ by one potential of the form (1) at low energies. The scattering length $a_s(np)$, calculated from the np data differs significantly from the experimental value $a_s(n,p)$ We have found (from pp -scattering data) that $a_s(n,p) = (17{,}1 \pm 0{,}1).10^{-13}$ sec. The coefficients $b_0 \dots b_3$ and $b'_0 \dots b'_3$ in the potential (1) for the pp and np systems were found separately:

| i | p – p $b_i \pm \Delta b_i$ | n – p $b'_i \pm \Delta b'_i$ |
|---|---|---|
| 0 | – 1,556 ± 0,241 | – 0,398 ± 0,232 |
| 1 | 34,55 ± 4,61 | 12,75 ± 4,40 |
| 2 | – 207,8 ± 18,5 | – 121,6 ± 17,3 |
| 3 | 250,6 ± 19,5 | 167,0 ± 17,9 |
| $\frac{\chi^2}{\bar{\chi}^2}$ | 0,965 | 1,09 |

The forms of the functions $V_C(x)$ for the pp and pp systems are very similar (fig.1). The energy dependence of $\delta_{^1S_0}(pp)$ and $\delta_{^1S_0}(np)$ is given in fig. 2 (curves 1 and 2). The curve 3 in fig. 2 shows the behaviour of the phase shift $\delta_{^1S_0}(n,p)$ calculated from pp data.

The behaviour of the phase shift $\delta_{^1S_0}$ for the pp and np system at low energies makes it possible to describe the phase shifts $\delta_{^1S_0}(p,p)$ and $\delta_{^1S_0}(n,p)$ by one potential of the type (1), although potentials for both systems are very similar.

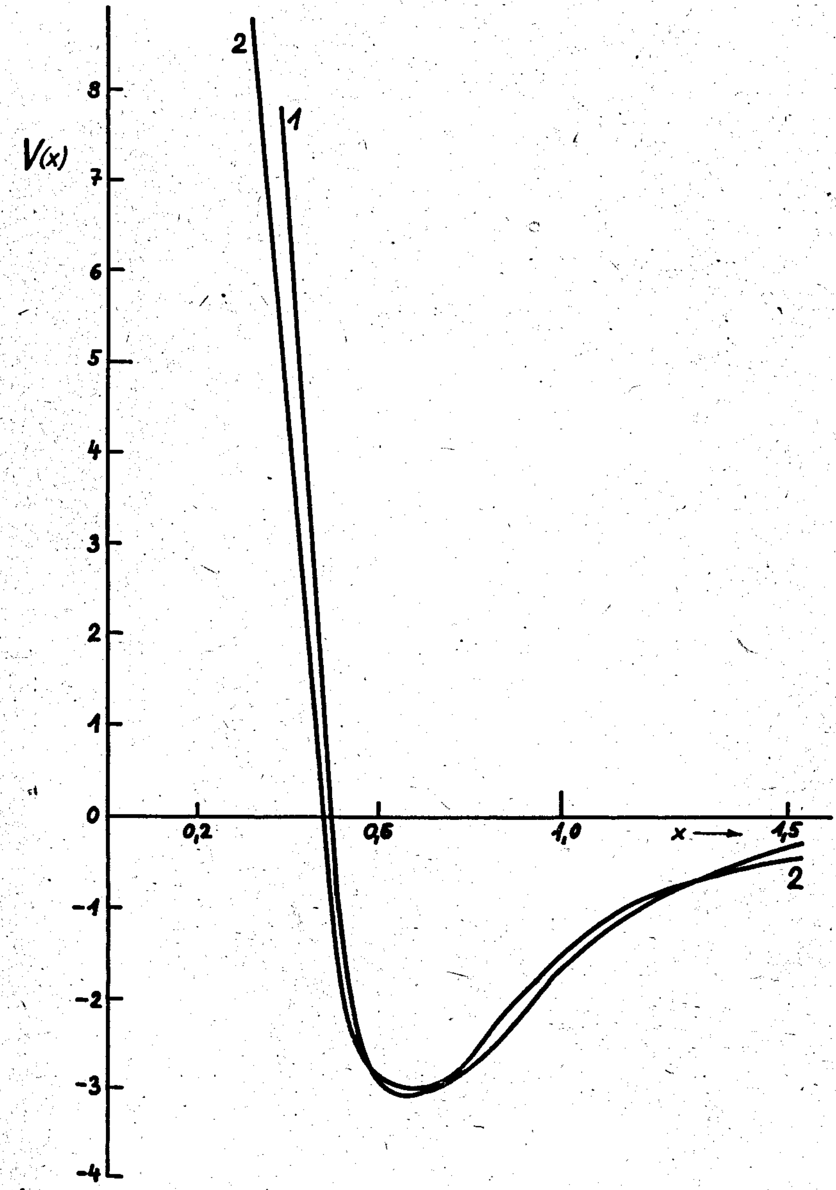
## References


1. Ю.М. Казаринов, В.С.Киселев, Ю.Н.Симонов. Препринт ОИЯИ Р-2241, Дубна 1965.
2. G. Breit. Proceedings of XII International Conference on High Energy Physics, Dubna, 1964.
3. R.A. Arnold, M.H. MacGregor. UCRL 14252 (1965).
4. Л.Д.Ландау, Я.А.Смородинский, ЖЭТФ 14, 269 (1944).
5. H. Bethe, P. Morrison. Elementary Nuclear Theory, N.Y., 1956.

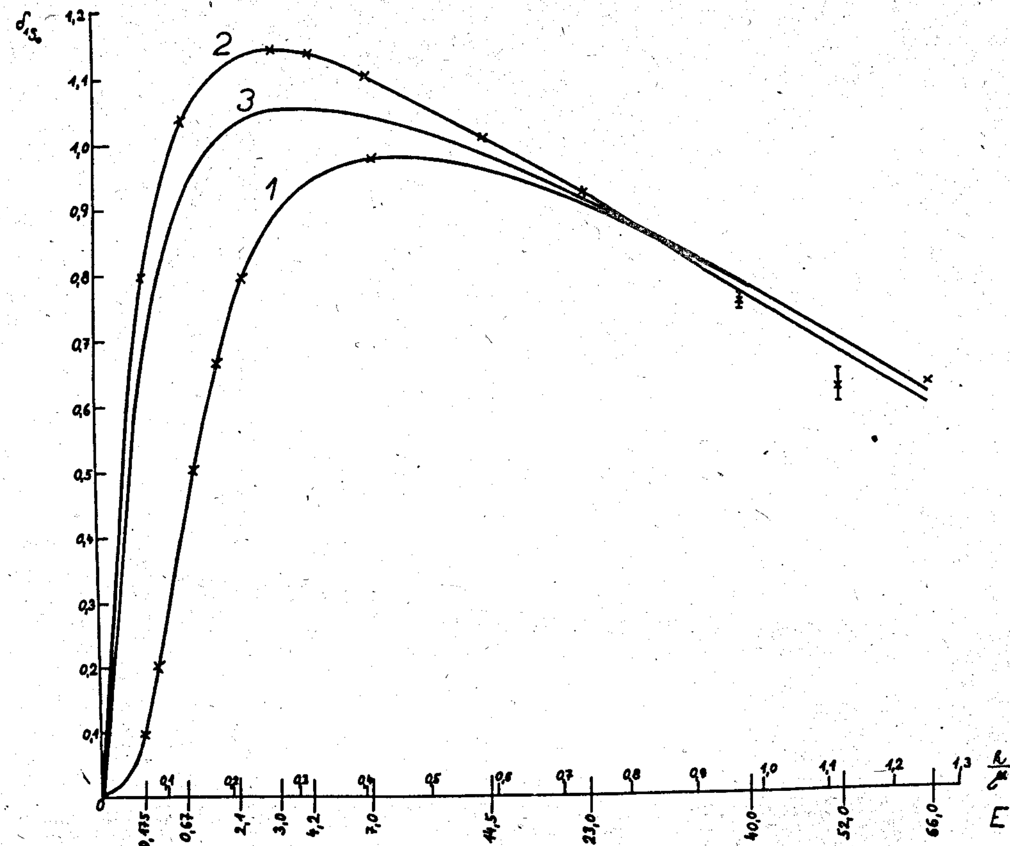


Received by Publishing Department
on November 18, 1965.




F i g. 1. Dependence $V_C(x)$ for p,p (curve 1) and for n,p (curve 2) scattering.




F i g. 2. Dependence of the phase shift $\delta_{1S_0}$ upon energy for p, p (curve 1) and np (curve 2) scattering. Curve 3 is the behaviour of $\delta_{1S_0}(n,p)$ obtained from (p, p) data.