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V.S.Stavinsky

ON THE RADIUS OF NN AND πN INTERACTIONS

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ON THE RADIUS OF NN AND πN INTERACTIONS

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Ставинский В.С.

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О радиусе NN и πN взаимодействия

В работе получена аналитическая связь экспериментально измеряемых величин полных сечений, параметра наклона и действительной части амплитуды рассеяния.

Препринт Объединенного института ядерных исследований.
Дубна, 1972

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On the Radius of NN and πN Interactions

The analytical bonds of the experimentally measured total cross sections, the slope parameter and the real part of the scattering amplitude are obtained.

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The slope parameter of the diffraction cone (B) often identified with "the effective radius of interaction" $(R_s = 2\sqrt{B})$, is determined by fitting the experimental data on elastic scattering and practically coincides with the expansion coefficient at $K^2 \theta^2$ of the scattering amplitude:

$$|f(\theta)|^2 = |f(0)|^2 [1 - (\frac{R_s}{2})^2 k^2 \theta^2], \qquad (1)$$

where θ is the scattering angle, K is the momentum of interacting particles; $f(\theta)$ is the scattering amplitude.

$$f(\theta) = \sum_{\ell=0}^{\infty} (a_\ell + i b_\ell) P_\ell (\cos\theta),$$

where

$$a_\ell = \frac{2\ell + 1}{2k} e^{-2\eta_\ell} \sin 2\delta_\ell$$

$$b_\ell = \frac{2\ell+1}{2k}\,(1-e^{-2\eta_\ell}\cos 2\delta_\ell\,)$$

and $\delta_\ell + i\eta_\ell$ is the wave phase shift with the momentum l. At small scattering angles one can confine oneself with the first term in θ^2 in the Legendre expansion:

$$P_\ell\,(\cos\theta) \simeq 1 - A_\ell\theta^2\,, \tag{2}$$

where

$$A_\ell = \frac{(2\ell+1)^2-1}{16}\,.$$

To this approximation, neglecting the terms of the order θ^4 the module square of the scattering amplitude takes the form:

$$|f\,(\theta)|^2 = |\,f(0)|^2\,\{\,1-2\theta^2\,\frac{\Sigma\, a_\ell\cdot\Sigma\, a_\ell A_\ell + \Sigma\, b_\ell\cdot\Sigma\, b_\ell A_\ell}{|\,f(0)\,|^2}\} \tag{3}$$

Equating the coefficients at θ^2 in eqs. (l) and (3) we obtain the ratio /1/ :

$$R_s^2 = \frac{2\pi R_0^4}{(1+a^2)\,\sigma_{tot}} - \frac{1}{2k^2} \tag{4}$$

in which

$$R_0^4 = \frac{1}{2k^4}\sum_{\ell=0}^{\infty}(2\ell+1)^3\,[\,1-e^{-2\eta_\ell}(\cos 2\delta_\ell\ -a\sin 2\delta_\ell\,)] \tag{5}$$

$$a = Re\,f(0)/Im\,f(0)$$

σ_{tot} is the total cross section.

The relation (4) is interesting in that independent experimentally measured values R_s, a and σ_{tot} turn out to be bound through the parameter R_0. The value

R_0^2, in a physical sense, is an average weighted of the value $(2\ell+1)_0^2$ in partial waves. According to the experimental data on the $p-p$ interaction, R^0 can be calculated for a /2,3,4/, total cross sections /3,5,6/ and R_s /7,8,9,10/. Figure 1 shows the calculation result (for energies 500, 1000 and 1500 GeV the total cross sections are taken from the theoretical paper /11/ and a is assumed to be equal to 0). For R_s we take the experimental data of the group of Heland et al. /9/. If R_s strongly changes with changing the momentum of interacting protons R_0, within the limits of errors, remains constant in the energy range from 1 to 1500 GeV. This experimental fact makes it possible to conclude that the increase of the slope parameter B with increasing energy is determined by decreasing a and σ_{tot} when energy increases. The decrease of the slope parameter with increasing the energy of interacting protons observed in "intersecting beam" experiments /9/, according to (4), confirms the theoretical prediction /11/ about increase of total cross sections in the energy range from 500 up to 1500 GeV. Unfortunately, the fact of decrease of the slope parameter with increasing energy cannot be considered to be proved at present. When measuring elastic scattering at smaller values of the momentum transfer $(k\theta)^2$, there have been obtained new data on the slope parameter B (U.Amaldi et al. /10/). The slope parameter increases with increasing energy. If R_0 does not depend on energy, $p-p$ total cross sections at 1500 must be equal to 33 mb according to (4).

Figure 2 shows the experimental data on the slope parameter R_s and the parameter R_0 for meson-nucleon interactions in the isotopic state $T=3/2$. For calculation, the experimental data on total cross sections from refs. /12,13/, on the ratio of the real-to-the-imaginary part of the scattering amplitude at energies higher than 7 GeV from ref. /14/ and at lower energies from the calculations on dispersion relations /15/ have been used. The values of R_s have been calculated from the experimental data on elastic differential cross sections from refs. /14,16,17/ using the value of the cross section in 0^o found by the optical theorem

Experimental data on the slope parameter R_s for pion-nucleon interactions are much less accurate than analogous data for $p-p$ interactions. The energy range is much lower. However with these reserves, in the case of pion-nucleon interactions the conclusion about the independence of R_0 on energy is rightful.

The independence of R_0 on energy permits to draw the following conclusions:

a) the slope parameter of the diffraction cone R_s, the ratio of the real-to-the-imaginary part (a) and the total cross section are interrelated according to (4);

b) at high energies the slope parameter of the diffraction cone $B = (\frac{R_s}{2})^2$ is inversely proportional to the total cross section σ_{tot};

c) as the value α is related to the total cross sections through dispersion relations, the dependence of the slope parameter B on energy is determined by the dependence of the total cross sections on energy;

d) the parameter R_0 for nucleon-nucleon interactions in the isotopic state with $T = 1$ and for pion-nucleon interactions with $T = 3/2$ is equal to

$$R_0\ (NN) = 1.01 - 1.02\,F\ ,$$

$$R_0(\pi N) = 0.84 - 0.86\ F\ ,$$

respectively.

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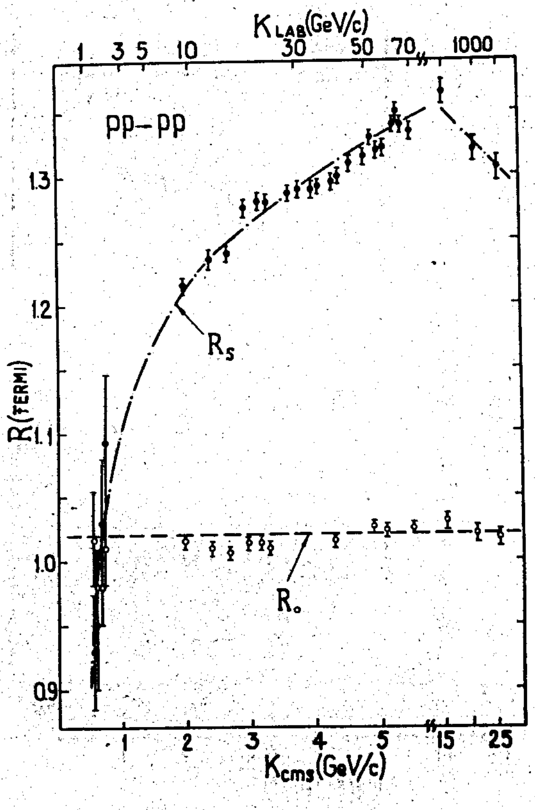

Fig.1. The dependence of parameters $R_s = 2\sqrt{B}$ and R_0 on the momentum in the c.m.s. for proton-proton interactions.

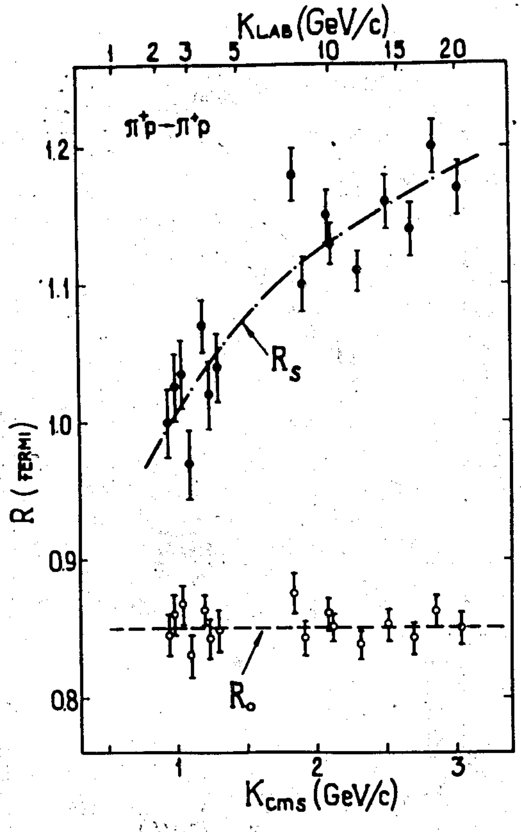

Fig.2. The dependence of parameters $R_S = 2\sqrt{B}$ and R_0 on the momentum in the c.m.s. for pion-proton interactions.