ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

ДУБНА

E2 - 8240

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1974

ЛАБОРАТОРИЯ
ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

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HOW LARGE IS THE PION CHARGE RADIUS FROM DUBNA - UCLA FORM FACTOR MEASUREMENTS?

Submitted *to Physics Letters B*

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The most precise and model-independent value of the pion charge radius $\langle r^2 \rangle = 6 \frac{dF_\pi(t)}{dt}\Big|_{t=0}$ can be obtained by direct measuring the pion form factor $F_\pi(t)$ in the space-like region. This can be done by scattering of high-energy pions by atomic electrons. The first successful experiment of this type has been recently performed by the Dubna-UCLA collaboration using the 50 GeV/c pion beam at Serpukhov /1/. All values of $F_\pi(t)$ obtained in this experiment correspond to very small momenta transfer ($-0.0353\ GeV^2 \le t \le -0.0138\ GeV^2$), being thus very suitable for determination of the pion charge radius.

The preliminary Dubna-UCLA value $\langle r^2 \rangle^{1/2} = 0.95 \pm 0.12$ fm reported by Shepard /2/ at the Spring Meeting of the Americal Physical Society in April, 1972 caused much excitement among physicists. Some of them /3/ began to speak about the violation of unitarity and analyticity because, if these concepts are applicable to the pion form factor, then there are good theoretical reasons to expect that the pion charge radius is not too different from the ρ-dominance predictions: $\langle r^2 \rangle^{1/2} \approx 0.62$ fm (see, e.g., /3,9/). Others /4,5/ investigated the consequences of such a large radius for the isovector p-wave $\pi\pi$-scattering phase shift. They came to the conclusion that the large radius suggested by the Dubna-UCLA collaboration would require a large δ_1^1 phase shift just above the threshold, what would have no dynamical explanation in the existing $\pi\pi$-scattering theory.

The final version [1] of the Dubna-UCLA value $\langle r^2\rangle^{1/2} = 0.78 \pm 0.10$ fm reported at the XVII International Conference on High Energy Physics, London, July, 1974, still seems to be too large when compared for instance, with the most recent values: $\langle r^2\rangle^{1/2} = 0.70 \pm 0.01$ fm or $\langle r^2\rangle^{1/2} = 0.68 \pm 0.01$ fm obtained in the analyses [6,7] of all experimental data on the form factor in the space-like and time-like regions simultaneously (excluding both the Dubna-UCLA and the Frascati measurements).

In the present note we investigate dependence of the particular parametrization of the form factor on the value of the radius.

In paper [1] the single-pole parametrization

$$|F_\pi|^2 = \frac{N}{(1-A\cdot t)^2} \tag{1}$$

has been used for the fit in the region of measurements and for the subsequent extrapolation to $t=0$. It is clear that the parametrization (1) should not be the best one.

We reanalysed the experimental data on $F_\pi(t)$ presented in [1] by means of a new model-independent method [8]. It was proposed by us for the determination of the charge radius of spin-zero light nucleus. However, without any modifications it can be applied to the present case. The method is based on the optimal use of the analytic properties of $F_\pi(t)$ in the whole cut complex t-plane.

First we map the entire cut t-plane onto an unifocal ellipse in the z-plane so that the experimental region is placed on the interval $-1 \le z \le +1$ and the cut on the ellipse. Next we use a search of the form

$$F_\pi[z(t)] = 1 + \sum_{n=1}^{M} A_n B_n [T_n(z) - 1], \tag{2}$$

where $T(z)$ are the Tschebyscheff polynomials, $B_n = (R^{2(n-1)} + R^{-2(n-1)} + 2\delta_{n-1,0})^{-1/2}$, R is the sum of the semi-axes of the ellipse and A_n are coefficients to be found from a fit.

Carrying out the fit with 22 experimental points from ref. [1] we find that according to minimization of the quantity $X = \chi^2 + \Phi$ (Φ is called the Cutkosky convergence test function) one should keep only one term in the series (2). We obtain $\chi^2 = 6.81$ for 21 degrees of freedom and the value $\langle r^2\rangle^{1/2} = 0.71 \pm 0.05$ fm.

We think that just this value should be considered as the pion charge radius resulted from the data of the Dubna-UCLA collaboration. It is in better agreement with other experimental data on the pion charge radius.

Thus, the serious difficulties discussed in refs. [3-5] are removed.

In conclusion we would like to stress that the optimal use of analyticity of the form factor has produced the nontrivial result: the shift of the central value of the radius and significant reduction of its error. Obviously, data on the form factor in the space-like region from future experiments should be analysed by using this method.

References

1. G.Adylov et al. JINR preprint, E1-8047, Dubna, 1974.
2. P.Shepard. Bull.Amer.Phys.Soc., 17, 435 (1972).
3. J.J.Sakurai. Preprint UCLA/72/TEP/63 (September, 1972).
4. D.N.Levin. S.Okubo. Phys.Lett., 42B, 233 (1972).
5. D.N.Levin, S.Okubo. Phys.Rev., 6D, 3149 (1972).
6. S.Dubnička, V.A.Meshcheryakov. JINR preprint, E2-7508, Dubna, 1973.
7. S.Dubnička, V.A.Meshcheryakov. JINR preprint, E2-7982, Dubna, 1974. To be published in Nucl. Phys., B, 1974.
8. S.Dubnička, O.V.Dumbrajs. JINR preprint, E2-8239, Dubna, 1974.
9. Dao Vong Dyc, Nguyen Van Hieu. Teor. i Matemat. Fizika, 3, 178 (1970).

Received by Publishing Department
on August 30, 1974.