REAL PART OF *p-p* FORWARD SCATTERING AMPLITUDE AT HIGH ENERGIES

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Recently there appeared a series of $(d\sigma/d\Omega)_0$ experimental data in *p-p* scattering at high energies from which it follows that at the energy 10 GeV a considerable exceeding of cross section above optical limit is observed [1—3, 12], At 10 GeV $\Delta \simeq 0,1$

$$\Delta = \frac{\left(\frac{d\sigma}{d\Omega}\right)_0 - \left(\frac{d\sigma}{d\Omega}\right)_{opt}}{\left(\frac{d\sigma}{d\Omega}\right)_{opt}} = \frac{[\mathrm{Re}\, A(0)]^2 + |B(0)|^2 + |D(0)|^2 + |E(0)|^2}{[\mathrm{Im}\, A(0)]^2}, \quad (1)$$

where A is spin averaged amplitude, $\mathrm{Im}\, A(0) = \frac{1}{8\pi}\sqrt{\lambda^2 - m^2}\, \sigma_t^{pp}$, λ is the total energy of proton in laboratory system; B, D, E are determined by the presence of spin-spin and tenzor terms in *p-p* interaction (it is implied that we write the *p-p* amplitude in the form of [4, 5]

$$M = A + B\sigma_{1n}\sigma_{2n} + i\sin\theta C(\sigma_{1n} + \sigma_{2n}) + D\sigma_{1p}\cdot\sigma_{2p} + E\sigma_{1q}\cdot\sigma_{2q},$$

$$\left(\frac{d\sigma}{d\Omega}\right)_0 = |M|^2; \quad \left(\frac{d\sigma}{d\Omega}\right)_{opt} = [\mathrm{Im}\, A(0)]^2,$$

where $\bar{n}, \bar{p}, \bar{q}$ are the orts of the vectors $k_i \times k_f$; $k_i \mp k_f$; respectively; k_i, k_f are the initial and final momenta of the incident proton in c. m. s.

It is interesting to know whether the observed values Δ are compatible with the values $\Delta_{dr} = [\mathrm{Re}\, A(0)/\mathrm{Im}\, A(0)]^2$ predicted on the basis of dispersion relations (d. r.) for *p*, $\bar{p}$-*p* forward scattering. The exceeding of the value Δ above the Δ_{dr} would show the presence of spin terms at such high energies.

The papers [6, 7] where attempts were made to calculate $\mathrm{Re}\, A^{pp}(0)/\mathrm{Im} A^{pp}(0)$ at high energies basing on d.r. with one subtraction cannot answer the question since the value $\mathrm{Re} A^{pp}(0)$ determined with the aid of such d. r. essentially depends on the choice of approach of σ_t^{pp} and $\sigma_t^{p\bar{p}}$ to their limiting values. If, for instance, at $\lambda \geqslant 20$ GeV $\sigma_t^{p\bar{p}}$ approaches limiting value by the low

$$\sigma_t^{p\bar{p}} = \sigma_t(\infty) + c\,\lambda^{-\eta} \quad (2)$$

then d. r. with one subtraction determine the real part [8, 9]

$$\mathrm{Re}\, A^{pp}(0) \approx -\frac{1}{2} c\lambda^{1-\eta}\, \mathrm{tg}\frac{\pi(1-\eta)}{2}. \quad (3)$$

Thus, the presence of small difference $\sigma_t^{p\bar{p}} - \sigma_t^{pp}$ in sufficiently large interval of energies can give the infinitely large contribution into the real part.

We have used the d. r. with two subtractions in a form presented in the paper [5]

$$\mathrm{Re}\, A^{pp}(\lambda) = \frac{\lambda-\lambda_1}{\lambda_0-\lambda_1}\mathrm{Re}\, A^{pp}(\lambda_0) - \frac{\lambda-\lambda_0}{\lambda_0-\lambda_1}\mathrm{Re}\, A^{pp}(\lambda_1) + \frac{f^2}{8\pi}\frac{(\lambda-\lambda_0)(\lambda-\lambda_1)}{(\lambda_\mu+\lambda)(\lambda_\mu+\lambda_0)(\lambda_\mu+\lambda_1)} + \frac{(\lambda-\lambda_0)(\lambda-\lambda_1)}{\pi}\left\{\frac{1}{8\pi}\int_m^\infty d\lambda' \sqrt{\lambda'^2+m^2} \times \left[\frac{\sigma_t^{pp}(\lambda')}{(\lambda'-\lambda)(\lambda'-\lambda_0)(\lambda'-\lambda_1)} + \frac{\sigma_t^{p\bar{p}}(\lambda')}{(\lambda'+\lambda)(\lambda'+\lambda_0)(\lambda'+\lambda_1)}\right] + F(\lambda, \lambda_0, \lambda_1)\right. . \quad (4)$$

$$F(\lambda, \lambda_0, \lambda_1) = \int_{\lambda_{2\mu}}^{m} \frac{d\lambda'\, \mathrm{Im}\, A^{p\bar{p}}(\lambda')}{(\lambda'+\lambda)(\lambda'+\lambda_0)(\lambda'+\lambda_1)}, \quad (5)$$

where $f^2 = 0,08$; m and μ are the proton and meson masses, $\lambda_\mu = \frac{\mu^2}{2m} - m$; $\lambda_{2\mu} = \frac{2\mu^2}{m} - m$. In d. r. of the type [4] the calculation of

$\mathrm{Re}\, A^{pp}(\lambda)$ proves to be insensible to the assumption about the slope of σ_t^{pp} and $\sigma_t^{\bar{p}p}$ at $\lambda \gtrsim 28$ GeV, since the subtraction constants $\mathrm{Re}\, A^{pp}(\lambda_{0,1})$ include the necessary information about the asymptotic behaviour $\sigma_t^{p,\bar{p}-p}$.

In order to estimate the integral over the non-observable region $F(\lambda, \lambda_0, \lambda_1)$ the three experimentally known values $\mathrm{Re}\, A^{pp}(\lambda_{0,1,2})$ are chosen and the value $F(\lambda_0, \lambda_1, \lambda_2)$ is determined. Then the value of $F(\lambda_0, \lambda_1, \lambda_2)$ is extrapolated to $\lambda_2 = \lambda$ with the aid of the formulae

$$F(\lambda, \lambda_0, \lambda_1) = \int\limits_{\lambda_{2\mu}}^{m} \frac{d\lambda' \,\mathrm{Im}\, A^{p\bar{p}}(\lambda')(\lambda'+\lambda_2)}{(\lambda'+\lambda_0)(\lambda'+\lambda_1)(\lambda'+\lambda_2)(\lambda'+\lambda)} = \frac{\xi+\lambda_2}{\xi+\lambda} \int\limits_{\lambda_{2\mu}}^{m} \frac{d\lambda' \,\mathrm{Im}\, A^{p\bar{p}}(\lambda')}{(\lambda'+\lambda_0)(\lambda'+\lambda_1)(\lambda'+\lambda_2)} = \frac{\xi+\lambda_2}{\xi+\lambda} F(\lambda_0, \lambda_1, \lambda_2) \quad (6)$$

$$\lambda_{2\mu} \leqslant \xi \leqslant m. \quad (7)$$

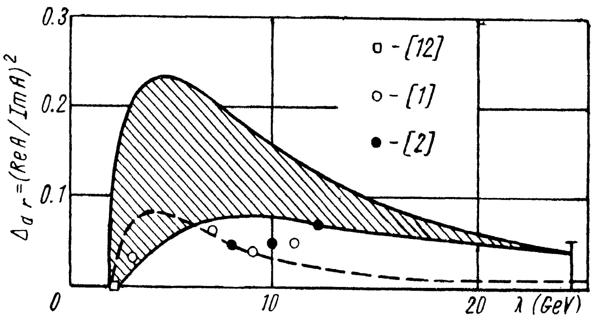
The condition (7) is, apparently, less strong than the assumption about the sign definiteness of the function $\mathrm{Im}\, A^{pp}(\lambda)$ $(\lambda < m)$ which can be proved from the unitarity conditions only for spinless particles *.

When calculating the integral over σ_t^{pp} in the interval $m \leqslant \lambda \leqslant m + 10$ MeV the values $\mathrm{Im}\, A^{nn} = [2k(\cot^2\delta_0 + 1)]^{-1}$ are taken, where $\cot\delta_0 = -(ka_{nn})^{-1} + 0.5\, r_0$; $a^s_{nn} = a^s_{np} = 23.6 \cdot 10^{-13}$ *cm*; $r_0 = 3.7 \cdot 10^{-13}$ *cm*. Due to the absence of the data on $\sigma_t^{\bar{p}p}$ at $\lambda < m + 50$ MeV the interval $\lambda < m + 50$ MeV was included into the integral over the non-observable region.

In order to decrease the contribution $F(\lambda, \lambda_0 \lambda_1)$ entering the result with considerable error the maximal values $\lambda_{0,1,2}$ are chosen. We have chosen $\lambda_{0,1}$ in the region of 1080—1380 MeV for which $\mathrm{Re}\, A^{pp}$ is given in the paper [11]. As a calibration point $\lambda = 24.5$ GeV has been chosen for which it is found in the paper [13] that $\Delta < 4 \cdot 10^{-2}$. According to this result we assumed that

$$-0.2 \leqslant \mathrm{Re}\, A^{pp}(24.5)/\mathrm{Im}\, A^{pp}(24.5) \leqslant 0.$$

The negative sign of $\mathrm{Re}\, A^{pp}(24.5)$ follows from the inequality $\mathrm{Re}\, A^{pp}(6.10 \text{ GeV}) < 0$[1] and the formulae (2), (3). (The change of the sign of $\mathrm{Re}\, A$ in the region of 20 GeV would mean the change of the sign of difference $\sigma_t^{\bar{p}p} - \sigma_t^{pp}$ in approximately the same region.) In Figure the calculated values of $\Delta_{d.r}$ together with the experimental data on Δ for the values $\Delta(24.5) = 0$ and $4 \cdot 10^{-2}$ are given. The shaded



Shaded area—the error band $\Delta_{d.r.} = [\mathrm{Re}\, A^{pp}/\mathrm{Im}\, A^{pp}]^2$ at $\Delta(24.5) = 4 \cdot 10^{-2}$, dotted line—the upper limit of $\Delta_{d.r.}(\lambda)$ at $\Delta_{d.r.}(24.5) = 0$. When calculating $\Delta_{\exp} = [(8\pi)^2 (d\sigma/d\Omega_0/(\sigma_t^{pp})^2 (\lambda^2 - m^2)] - 1$ the mean values σ_t^{pp} are taken.

area gives the band of the errors which are connected with the uncertairty in the extrapolation or $F(\lambda_0, \lambda_1, \lambda_2)$. The errors connected with the uncertainties $\mathrm{Re}\, A^{pp}(\lambda_{0,1})$ and $\sigma_t^{p,\bar{p}-p}$ are or the same or smaller order. The result is almost independent of the choice of the asympototics (when including the constant difference $\sigma_t^{\bar{p}p}(\infty) - \sigma_t^{pp}(\infty) \simeq 1 \div 2mb$ we have the change of $\mathrm{Re}\, A^{pp}(\lambda)$ within 2—3%).

Thus, the values $\Delta(24.5) < 4 \cdot 10^{-4}$ are quite compatible with the data [1, 2] without an account of spin interactions though for definite answer more precise measurements at 24.5 and 10 GeV are necessary.

In the paper by Söding [7] on the basis of d. r. with one subtraction and with the asymptotics $\sigma_t^{\bar{p}p} = \sigma(\infty) + C \cdot \lambda^{-0,72}$ the values of $\mathrm{Re}\, A^{pp}$, close to our results, are obtained. Since the result by Söding must be very sensible to the asymptotic behaviour $\sigma_t^{\bar{p}p} - \sigma_t^{pp}$, the coincidence of our and Söding's results can be considered as an indication that in the case of p, $\bar{p}$-p the approach to the Pomeranchuk's limit proceeds «fast».

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* In spin particle annihilation the change of the spectral function sign in the region $\lambda < m$ is not excluded [10].

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