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Partial-wave analysis and optical model for p̄–p scattering

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Abstract. The partial-wave analysis of the p̄–p scattering amplitude in the energy region 50–180 MeV is performed and the results compared with those of the optical model.

This paper deals with the partial-wave analysis of the p̄–p scattering experiment (Amaldi *et al.* 1963, see also Amaldi *et al.* 1966, Conforto *et al.* 1968) in the energy region 50–180 MeV. The experiment yields the cross sections σ_{el}, σ_{ab}, σ_{tot}, σ_0 (zero prongs) and the angular distribution of events n_i as a function of $\cos\theta_i$, the index i standing for any of 40 intervals $\Delta\cos\theta_i$, where θ is the scattering angle. We will be using centre-of-mass co-ordinates throughout.

When discussing the experiment in terms of an optical model or any other suitable model, it becomes apparent that a better physical insight into the problem can be reached through the partial-wave analysis of the scattering amplitude.

Since the experimental data are insufficient for a complete analysis, they must be supplemented by additional hypotheses. We chose the following, which will be partly justified by physical reasoning:

(i) Because σ_{ab} is much larger than σ_{el}, we shall assume the scattering amplitude to be purely imaginary. This is consistent with the optical model which deals only with absorption.

(ii) Also in agreement with the optical model is the hypothesis that the scattering amplitude changes sign at the minimum in the experimental angular distribution. The calculation was also performed for the case when no change in sign occurs.

(iii) No account was taken of the spin of the particles.

Let us write the scattering amplitude as

$$f(\cos\theta) = i\sum_l (2l+1)A_l\mathrm{P}_l(\cos\theta)$$

and the elastic cross section as

$$\sigma_{\mathrm{el}} = 2\sum_l (2l+1)A_l^2 = \frac{4\pi}{4k^2}\sum_l (2l+1)|\eta_l|^2.$$

The partial-wave analysis was performed by using the method of maximum likelihood.

Figure 1 shows the partial wave amplitudes $A_l/(2\pi)^{1/2}$ for the s, p, d and f waves as a function of the laboratory kinetic energy of p̄. In the same figure the values of $|\eta_l|/2k$ obtained from the optical model for a diffuse disk, with absorption coefficient $a = 1$ for $\rho < R$ and $a = \exp\{-(\rho^2-R^2)/\rho_0^2\}$ for $\rho > R$, have been plotted. The model parameters R and ρ_0 were determined from σ_{ab} and σ_{tot} separately for each of the nine energy intervals. The amplitudes plotted in figure 1 are found to satisfy the optical theorem very well. This supports the validity of hypothesis (i), although the check is not stringent.

Better agreement between results of the model and those of the partial-wave analysis is obtained when hypothesis (ii) is made for the partial-wave analysis, which would be expected as the optical model does yield a change in sign for the scattering amplitude. Because in the optical model the s waves are completely absorbed, the partial-wave analysis yielding a larger s component indicates that a small real part of the scattering amplitude should be present. It should be noted that the smaller s-wave contribution yielded by the model leads through normalization to a larger p-wave contribution. As far as the angular distribution is concerned, it is easy to see that the larger contribution of p waves yielded by the optical model corresponds to stronger backward scattering. As mentioned above, this

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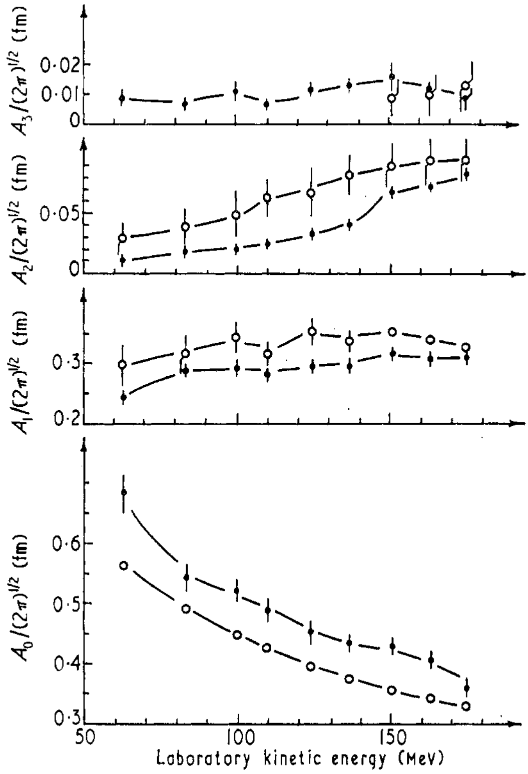

Figure 1. Results of the partial-wave analysis for s, p, d and f waves (full circles) as compared with the results of the optical model (open circles). The errors are estimated from the width of the maximum likelihood function and the experimental errors on σ_{tot} and σ_{el}.

should be at least partly corrected by the introduction of a real part of the scattering amplitude. The contribution of d waves slowly increases with energy as expected.

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