Measurements of spin rotation parameters in proton elastic scattering from ^{58}Ni at E_p=295 MeV and medium effects

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We have measured spin rotation parameters Q of elastic scattering from ^{58}Ni using 295 MeV polarized protons under the program E69 at RCNP. The measurements include the higher momentum transfer region ($q \leq 3.6\,\mathrm{fm}^{-1}$). By measuring spin rotation parameters and combining these data with the existing differential cross section and analyzing power data, we have performed a "complete" experiment for proton elastic scattering.

The experimental results were analyzed using the RIA model of Murdock and Horowitz [1], and the RIA model of Tjon and Wallace (IA2) [2]. In the analysis given in Ref. [3] of cross sections and analyzing powers, it was necessary to use realistic densities of the target nuclei and to modify the coupling constants between nucleons and mesons and the masses of exchanged mesons in the N-N interaction as a medium effect. We have introduced the parameters a_j, $\bar{a}_j$, b_j and $\bar{b}_j$ representing the medium effect and adjusted the coupling constants and masses of σ and ω mesons according to the following formula:

$$g_j^2, \quad m_j \quad \longrightarrow \quad \frac{g_j^2}{1 + a_j\left(\frac{\rho(r)}{\rho_0}\right)}, \quad m_j\left(1 + b_j\left(\frac{\rho(r)}{\rho_0}\right)\right), \quad (j = \sigma, \omega).$$

The predictions of both Horowitz's and Wallace's models deviate from the experimental results of spin rotation parameters at large angles. Using the same parameter values obtained in our previous work, we calculated the spin rotation parameters Q, which can also reproduce the experimental results well.

Using our complete scattering data for elastic scattering, we thoroughly surveyed parameter values representing medium effects. We started this search using the parameters of our previous work obtained from the experimental data of cross sections and analyzing powers. The parameter values obtained from the χ^2-minimum including the spin rotation parameter data are designated "Set1" in Table 1. In order to investigate the correlations among the parameters in detail and confirm the uniqueness of the parameters, we studied a χ^2-minimum for every pair of a_σ- and a_ω-values, where the other 6 parameters were freely searched. We found a new broad and deep valley beside a local minimum around the Set1 parameter values, as shown in Fig. 1. The χ^2-minimum ("Set2" parameters) of the new broad valley is the best fit and is much smaller than that of the "Set1" parameters. In this valley every parameter

Table 1: Three sets of parameter values determined by fitting to the experimental data.

	g_σ^2		m_σ		g_ω^2		m_ω		$\frac{\chi^2}{N-F}$
	a_σ	$\bar{a}_\sigma$	b_σ	$\bar{b}_\sigma$	a_ω	$\bar{a}_\omega$	b_ω	$\bar{b}_\omega$	
prev.	0.1943	0.2506	−0.0009	0.0766	0.2373	0.3448	0.0100	−0.0219	19.5
Set1	0.1059	−0.0874	0.0475	0.0887	0.2633	0.1571	0.0005	−0.0212	13.4
Set2	0.3438	−0.1878	−0.0883	−0.1793	1.0810	0.4529	−0.2651	−0.3081	11.2
Set3	0.2228		−0.0688		0.8274		−0.2366		12.3

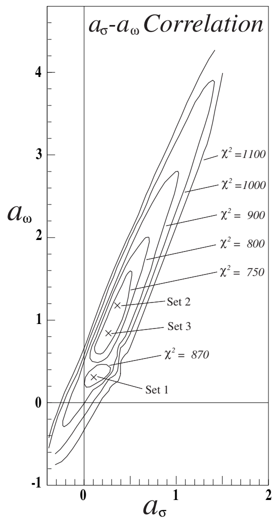

Figure 1: A χ^2-map for each pair of a_σ- and a_ω-values.

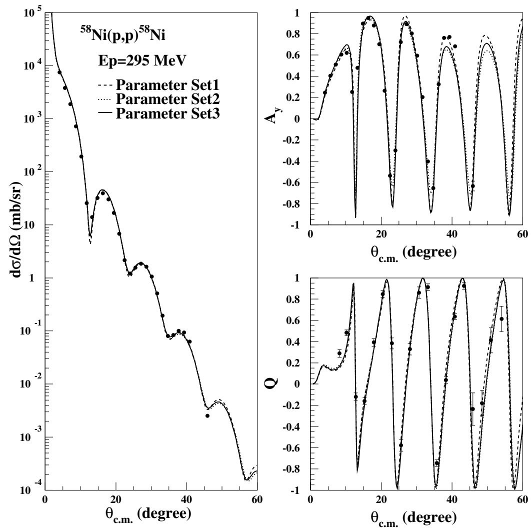

Figure 2: The experimental results compared with the calculations using three kinds of parameter sets given in Table 1.

set which has a χ^2-value less than 750 in Fig. 1 can explain our experimental results almost equivalently. Here, each parameter of meson masses varies smoothly and the structure of the χ^2-map is simple, but the density dependence of coupling constants can change irregularly because the number of free parameters was too large. There are parameter sets for which real and imaginary parts of the density dependence of coupling constants and masses for each meson are almost equal. Thus in order to reduce the number of free parameters we assumed that the density dependences of the real parts and imaginary parts of the scattering amplitude were equal. With this assumption we obtained the optimized parameter set presented in Table 1 as "Set3" near the Set2. At present, it seems that the Set3-parameter is the most suitable for the comparison with various theories. The results of the fitting are displayed in Fig. 2.

According to Set3 given in Table 1, the coupling constants and the masses of the mesons decrease as presented by g_σ^*/g_σ=0.90, m_σ^*/m_σ=0.93, g_ω^*/g_ω=0.74 and m_ω^*/m_ω=0.76 at normal density. They also scale approximately; $g_\sigma^*/g_\sigma \approx m_\sigma^*/m_\sigma$ and $g_\omega^*/g_\omega \approx m_\omega^*/m_\omega$. These reduction values at normal density are similar to the values predicted by various theoretical models [4, 5, 6]. However, among these density dependent parameters we found strong correlations and thus there exist large ambiguities, The best parameter set will be determined by considering the consistency of the present data with that for other incident energies and nuclei. At the same time, suggestions from the theoretical side are also necessary to firmly establish the parameter set accounting for the medium effect.

References

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