Delta M.E. Optimization

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Abstract

The HMS δ matrix elements have been analyzed, optimized, and compared to the pre-existing matrix elements used in our ENGINE. It has been found that the newly analyzed matrix elements offer a slight improvement over the older matrix elements when reconstructing the elastic scattering peaks for the reaction $^{12}C(e,e)^{12}C$ with electron beam energy = 884.25 MeV and HMS angle 23.55°.

1 Introduction

The HMS δ matrix elements were optimized using a method outlined in a Hall C document which describes the CMOP software package. [1]. The method involves a singular value decomposition technique along with a $\chi^2/d.f.$ minimization to fit 126 parameters. These parameters are determined by correcting elastic $^{12}C(e,e)^{12}C$ scattering peaks. The centroids of the elastic scattering peaks were made to fall at seven different positions along the focal surface by changing the HMS dipole field to give different values of its central momentum, p_c, while keeping the beam energy and electron scattering angle fixed and thereby keeping the momentum of the scattered electron fixed at $p_s = 880.5$ MeV/c. The δ variable is defined to be

$$\delta(p_s, p_c) = 100 \cdot \left(\frac{p_s - p_c}{p_c} \right). \tag{1}$$

Since the momentum of the scattered electron was not varied during the data gathering and the HMS field is the experimental parameter that was changed for each of the seven measurements, the seven values of δ are referred to by their HMS field settings rather than p_c:

The seven delta peaks and the magnetic field associated with p_c are given in table 1. The values of p_c and thus δ are obtained from the equation,

$$p_{c_i} = B_{field_i} \cdot \frac{1.009}{0.2765}.$$

Figure 1 shows the reconstructed delta peaks for each field setting before any correction by CMOP is made.

Table 1: **Dipole Field, Calculated, and Measured δ.**

i	Magnetic Field (T)	Calculated δ (%)	P_cent_i (GeV)	Measured δ (%)
1	0.2534	0.9247	-4.78	-4.97
2	0.2473	0.9024	-2.43	-2.65
3	0.2413	0.8805	0.01	-0.23
4	0.2352	0.8583	2.59	2.29
5	0.2292	0.8364	5.27	4.91
6	0.2232	0.8145	8.10	7.79
7	0.2172	0.7926	11.09	10.71

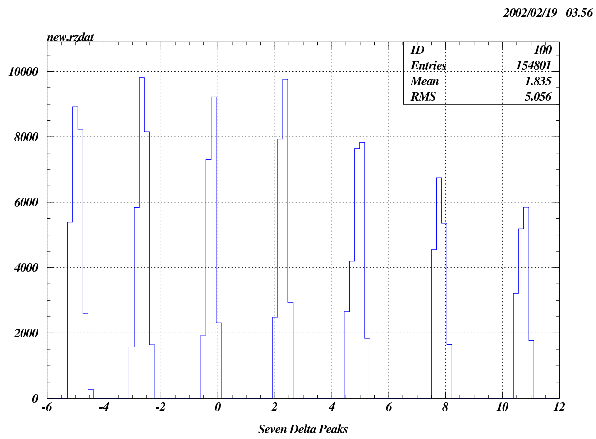

Figure 1: Delta Peaks before Corrections

Table 2: **Difference for Ground State and First Excited State.**

Matrix Elements	Ground State δ	First Excited State δ	$\Delta\delta$	Δ Energy (MeV)
Old	-0.18	-0.83	0.65	5.72
New	-0.20	-0.78	0.58	5.11

2 Systematic Error

The largest contributions to the sytematic error come from the uncertainty in the beam energy and the uncertainty in the HMS field which gives rise to the uncertainty in p_c.

The error in δ due to the uncertainty in the beam energy is given by

$$\Delta\delta_{E_{beam}} = \frac{100}{p_c} \cdot \frac{1}{(1 + \frac{2E_{beam}}{M_C} sin^2(\theta/2))^2} \cdot \Delta E = 0.0510\%. \quad (2)$$

The Accelerator Division assures us that the beam energy for these delta scans was $E_{beam} = 884.25 \pm 0.09$ MeV although we use a more conservative estimate $E_{beam} = 884.25 \pm 0.45$ to obtain $\Delta\delta_{E_{beam}} = 0.0510\%$.

Energy loss effects for the electron as it passes through the carbon target and the HMS spectrometer have also been studied. For these kinematics, the total energy loss for the electron was small and considered negligible. This question will be addressed in a forthcoming report.

3 Comparison with previous matrix elemnts

Although the elastic peaks of $^{12}C(e,e)^{12}C$ were used to generate new matrix elements, we also looked at electrons scattering from the first excited state of carbon to measure the success of the optimization. The first excited state of carbon is 4.4 MeV above the ground state and well within the resolving power of the HMS. By looking at carbon data taken during E93-038 we made the uncomfortable discovery that when using the old matrix elements the HMS was reconstructing a peak for which the first excited state is centered 5.72 MeV above the ground state. This represents a 30.0% percent difference from the expected 4.4 MeV. With the newly optimized matrix elements, we find that the reconstructed peak of the first excited state is centered 5.11 MeV above the ground state. Use of the newly optimized matrix elements reduced the difference between the measured and standard excitation of the first excited state to 16.1%, an improvement by nearly a factor of 2.

These centroids were determined by fitting each peak with a Gaussian curve. While the difference in energy between the first excited state and the ground state does not agree with the known value of 4.4

MeV, the newly optimized matrix elements do show a clear improvement. For the energy differences quoted here, the $\delta = 0$ setting was used. The reason for this choice is somewhat arbitrary but it was with the δ acceptance in mind. Also, it is clear that the peaks generated with the new matrix elements are better defined and contain more events. For the elastic peak, in the range $-0.35 \leq \delta \leq 0$, the new peak has about 110% of the counts found with the previous matrix elements.

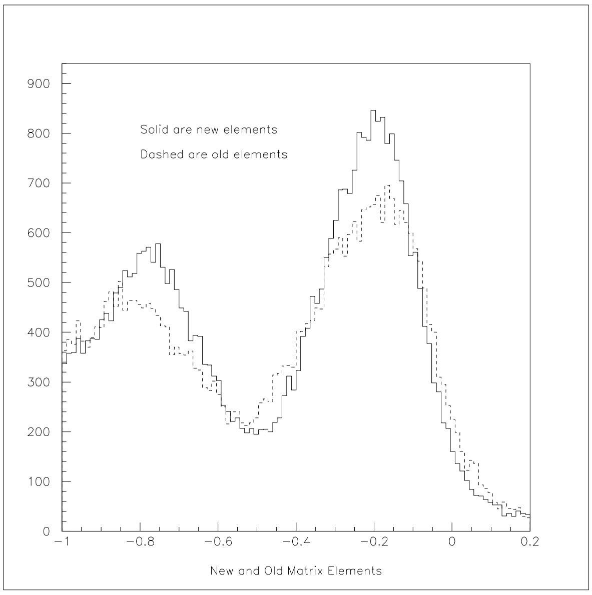

Figure 2: Old and New Matrix Elements

4 Conclusion

The newly optimized matrix elements offer a significant improvement to the pre-existing matrix elements. In tests conducted using the elastic peak of the $^{12}C(e,e)^{12}C$ reaction, the new matrix elements outperformed the pre-existing matrix elements in that they do a better job of resolving the ground state and the first excited state of carbon. This also improved the agreement between the energy of the first excited state and its known value by a factor of two. The remaining disagreement is probably due to not knowing the dispersion of the spectrometer well enough and cannot be improved by further work on the matrix elements. [1]

References

[1] Ketevi Assamagan, Hall C Matrix Optimization Package

[2] Dipangkar Dutta, *The (e,e'p) Reaction Mechanism in the Quasi-Elastic Region*, Hall C Ph.D. Thesis.

[3] Eric Christy, As yet unpublished Hall C Report

[1] In a yet to be circulated report by Eric Christy[3] it is noted that there is an offset to the HMS δ variable on the order of -0.31% which is not accounted for by the Hall C online replay ENGINE from which we developed our own ENGINE. This correction expresses a systematic correction to the dipole field in terms of p_c and is determined empirically from studies of the HMS optics done in 1998.