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Electromagnetic Form Factors for the 14.39 and 17.50 MeV Levels of ^{9}Be

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The form factors for the 14.39 and 17.50 MeV levels of ^{9}Be have been measured for momentum transfer in the range between 0.47 and 1.08 fm^{-1}. Radiative widths for the transitions and the transition radii were also obtained. The results are wnsistent with the attribution of an M1 transition to the 14.39 MeV level and an M2 to the 17.50 MeV level.

Os fatores de forma para os níveis de 14.39 e 17.50 MeV do ^{9}Be foram medidos na região de transferência de momento de 0.47 a 1.08 fm^{-1}. As larguras radiativas para as transições e os raios de transição foram também obtidos. Os resultados são consistentes com a atribuição de transição M1 para o nível de 14.39 MeV e de M2 para o nível de 17.50 MeV.

1. Introduction

Electromagnetic form factors obtained by scattering of electrons from nuclei are a very rich source of information on nuclear structure since their comparison with theoretical prediction constitutes a rigorous test of nuclear models. In this work, the form factor of the 14.39 and 17.50 MeV ^{9}Be levels were measured at momentum transfers between 0.47 and 1.08 fm^{-1}. These levels and another two at energies of 16.65 and 16.97 MeV were previously studied at Darmstadt by Clerc, Wetzel and Spamer[1] at low momentum transfer. Their experimental results show that the 14.39 and 16.97 MeV levels are excited by M1 transitions and the 16.65 and 17.50 MeV levels by M2 or pure spin flip El. They also obtained transition radii and radiative widths for these levels.

Shell model calculations on ^{9}Be were performed by French, Halbert and Pandya[2], by Soper, quoted by Woods and Wilkinson[3], and more recently by Barker[4]. Barker, using intermediate coupling and considering only states of the configuration $1s^4$ $1p^5$, predicts eight levels of negative parity in the region of excitation energies between 14 and 18 MeV, three with

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isotopic spin $T = 3/2$ and five with $T = 1/2$. One of the first three is the 14.39 MeV level, known to have $T = 3/2$ and to which was assigned[5,6] spin $J = 3/2$.

The 17.50 MeV levels has positive parity and no wave functions for it exist in the literature; however, the generalized Helm model of Rosen, Raphael and Uberall[7] is used to determine the multipolarities of the transitions, the radiative widths and the transition radii of both levels.

2. Experimental Method

This experiment was performed using the electron scattering facility at the 140 MeV linear accelerator of the University of Saskatchewan described by Katz et *al*[8].

Four spectra were taken with the magnetic spectrometer placed at an angle of 155^0 to the beam. Two other spectra were also measured at an angle of 125^0 to check longitudinal contributions to the transitions. The target used was approximately 10^{-3} radiation lengths thick. The overall energy resolution was about 0.4% for the ^{9}Be elastic peaks and was not sufficient to resolve completely the three peaks appearing around the excitation energy of 17 MeV.

3. Data Analysis and Experimental Results

Figures 1 and 2 show two of the six spectra obtained, after subtraction of the radiation tail. The usual radiative corrections (Tsai) to the elastic peak were applied in order to calculate the radiation tail. To get the area under inelastic peaks, best fits with up to three Gaussians plus a linear background were made to the data.

The function used was

$$f(E) = a + bE + \sum_j A_j \exp\left[-B_j (E - E_{0j})^2\right]$$

These best fits were checked by applying the "chi" square test. The value of the "chi" square in each fit was close to the number expected for a good fit.

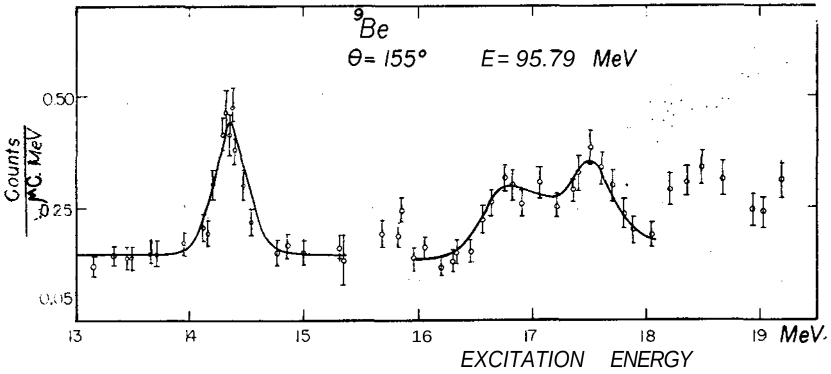

Fig. 1 — Radiation tail subtracted spectrum. The solid line is the best fit.

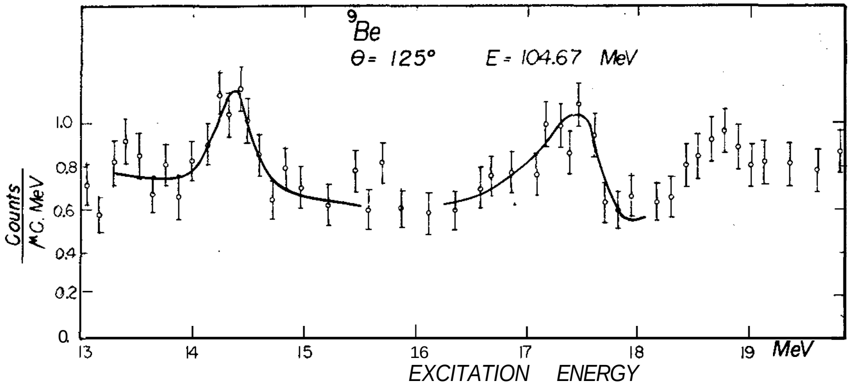

Fig. 2 — Radiation tail subtracted spectrum. The solid line is the best fit.

In order to obtain the inelastic form factor, ^{12}C elastic scattering was measured under the same beam conditions as a cross calibration. The elastic form factor of ^{12}C was taken as that given by the harmonic oscillator shell model with parameters

$$a = 4/3, \qquad a = 2.42 \text{ fm}, \qquad a = \text{r.m.s. radius}$$

The cross section for inelastic scattering of electrons by a nuclear level in first order Born approximation can be written as:

$$\frac{d\sigma}{d\Omega} = \sigma_{\mathrm{M}} \left| F_{\chi}(q, \theta) \right|^2,$$

where

$$|F_\chi(q,\theta)|^2 = |F_L(q)|^2 + \left[\frac{1}{2} + \tan^2\frac{\theta}{2}\right] |F_T(q)|^2$$

and σ_M is the Mott cross section. F_L and F_T are the longitudinal and transverse form factors for the nuclear transition. The results displayed in Figs. 3 and 4 show that the longitudinal contributions, if any, are small and we assumed that the transitions are totally transverse.

The multipolarities were determined by making a best fit of the form factor predicted by the generalized Helm model1[7] to the experimental points. In this model, the expression for the magnetic form factor $F^m(q)$ is the following[7]:

$$F^m_\lambda(q) = \frac{q}{2M} f(q) \left(\frac{\lambda}{2\lambda+1}\right)^{1/2} \gamma(\lambda+, J_0 J) j_{\lambda+1}(qR) + \left(\frac{\lambda+1}{2\lambda+1}\right)^{1/2} \gamma(\lambda-, J_0 J)\, j_{\lambda-1}(qR)$$

where $f(q) = \exp(-t^2q^2/2)$ and t = thickness of nuclear surface.

The best fits of this expression to the experimental points obtained by considering the 14.39 MeV transition as M1 and the 17.50 MeV as M2 and taking R = 2.6 h and γ = 0.26 h are presented in Figs. 5 and 6, The parameters y are shown in Table 1. With these values of the parameters, the ground state radiative widths and transitions radii of table 2 were obtained (see Ref. 7).

The errors in Γ^0_γ and R_{tr} are estimated to be about 20% and 30% for the 14.39 and 17.50 MeV levels, respectively. As a check on the values of the parameter γ, the radiative widths and transitions radii were also determined in the usual way, extrapolating the form factor to low q. The results are consistent with those quoted in table 2.

Level (MeV)	Pararneters
14.39	$\gamma(1-, J_0J) = 0.256$
	$\gamma(1+, J_0J) = 0.556$
	$\gamma(2-, J_0J) = 0.509$
17.50	$\gamma(2+, J_0J) = 0.690$

Table 1 — The parameters, γ, of the generalized Helm model for the 14.39 MeV and 17.50 MeV transitions.

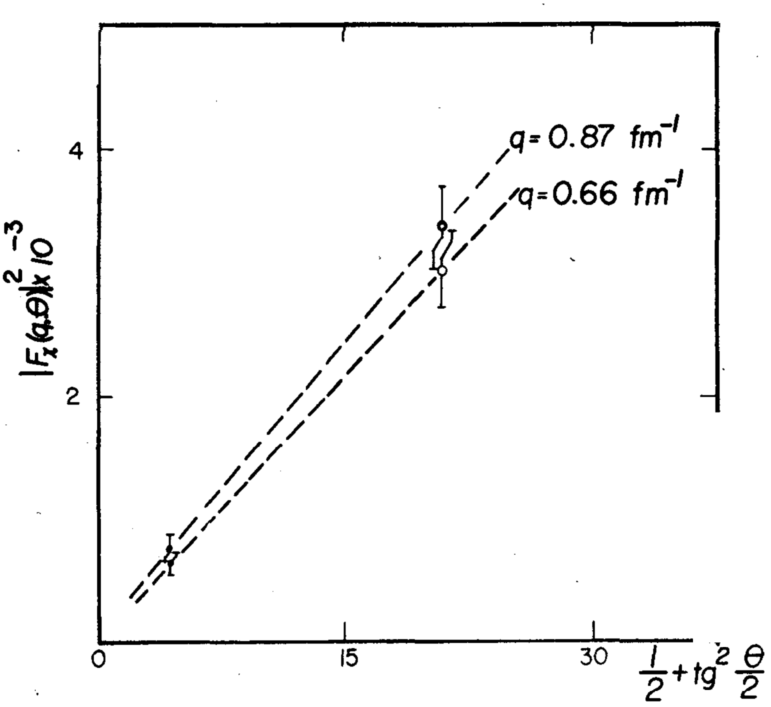

Fig. 3 Separation of the longitudinal and transverse contributions to the form factor for the 14.39 MeV level.

Level (Mev)	Γ_γ^0 (eV)		$\frac{\Gamma_\gamma^0}{\Gamma_{\gamma W}^0}$		R_{tr} (fm)	
	Present	Clerc	Present	Clerc	Present	Clerc
14.39	6.7±1.4	10.5±1.5	0.11±0.02	0.17	1.6±0.3	2.4±0.4
17.50	0.11±0.034	0.7±0.2	1.0±0.3	6.6	2.8±0.9	4.3±0.6

Table 2: Here, $\Gamma_{\gamma W}^0$ = Weisskopf unit

4. Discussion

The experimental results show that the 14.39 and 17.50 MeV levels are excited by M1 and M2 transitions respectively and so the parities are negative and positive, in agreement with previous work. The ground state radiative widths and transition radii, compared with the measurements of Clerc, Wetzel and Sapmer[1], are consistently smaller but still within statistical errors.

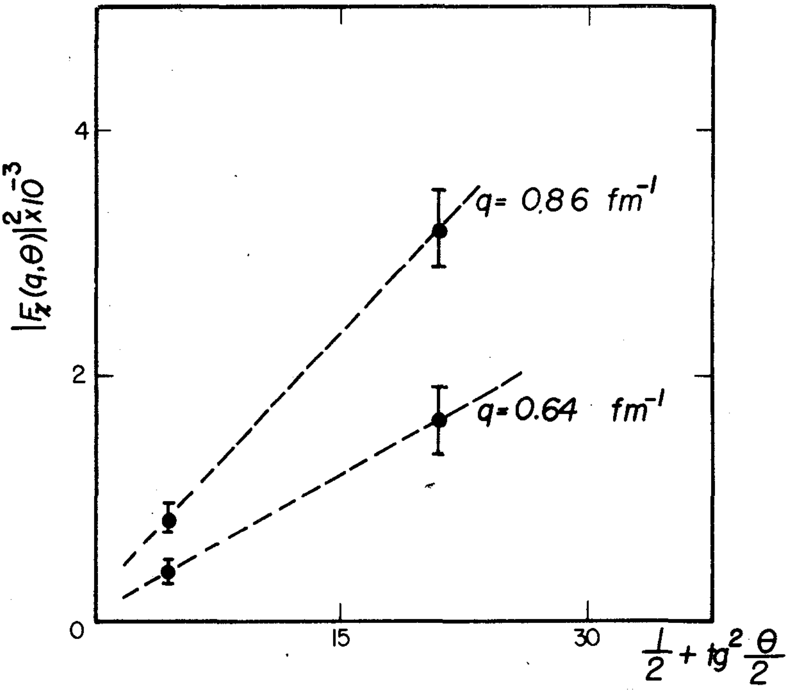

Fig. 4 — Separation of the longitudinal and transverse contributions to the form factor for the 17.50 MeV level.

Shell model eigenfunctions for the ^{9}Be states were calculated by Barker[4], assuming intermediate coupling, obtaining for the 14.39 MeV level a value $(2J+1)\Gamma_\gamma = 21$ eV. Assuming $J = 3/2$, this gives 5.3 eV for the radiative width as compared with the experimental value of (6.7 ± 1.4) eV of this work. These results support the assignment made to the 14.39 MeV level as having $T = 3/2$ and $J = 3/2^-$.

The 17.50 MeV level, since the parity is positive, should belong to a configuration $1s^4 1p^4 1d^1$ or $1s^4\ 1p^4\ s^1$. No available calculations exist at this excitation energy but the radiative width indicates that the level is not collective. The application of the generalized Helm model favours the M2 assignment instead of a pure E1 spin flip. The spin is $-7/2$.

The peak at 15.99 MeV, reported by Clerc *et al.*[1] and others above 18 MeV also appears in our spectra but the statistical errors were too large to investigate it.

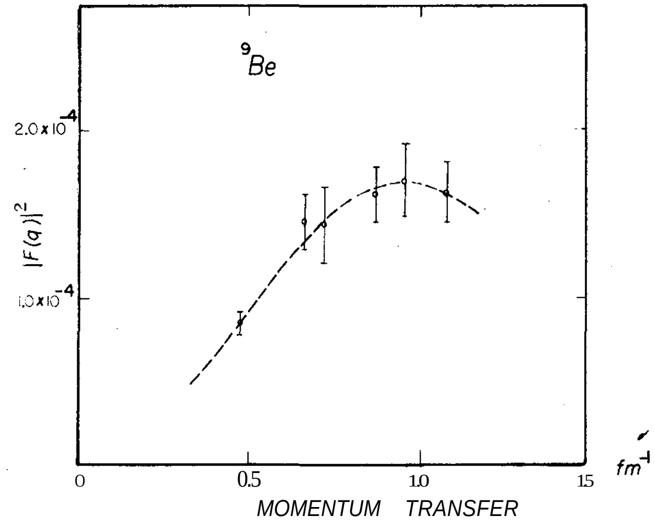

Fig. 5 — Helm model fit to the form factor for the 14.39 MeV level

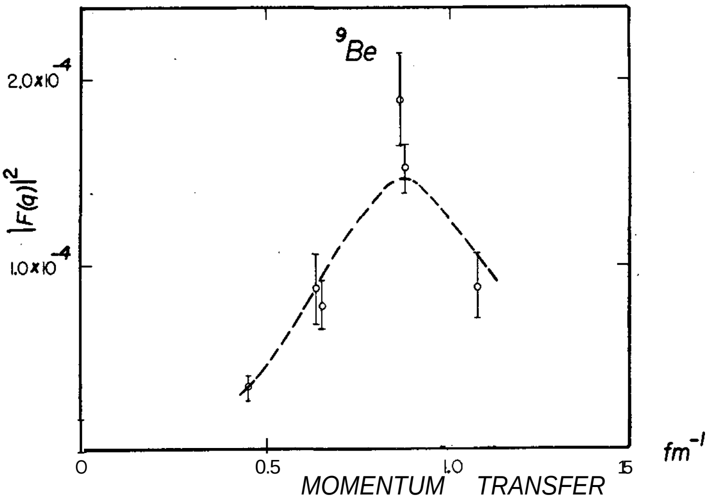

Fig. 6 — Helm model fit to the form factor for the 17.50 MeV level.