Electron- and photon-induced proton knockout from ^{209}Bi

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Cross sections have been measured for the ^{209}Bi$(e,e'p)^{208}$Pb and ^{209}Bi$(\gamma,p)^{208}$Pb reactions using electrons at $E_e = 293$ and 412 MeV, and tagged photons at mean $E_\gamma \sim 43.7$ and ~ 52.0 MeV, respectively. The ^{209}Bi$(e,e'p)^{208}$Pb results are compared to complete distorted wave impulse approximation calculations, from which it is deduced that a model of ^{209}Bi based on a $1h_{9/2}$ proton orbiting an inert ^{208}Pb core has a high degree of validity. The interpretation of the ^{209}Bi$(\gamma,p)^{208}$Pb results makes use of the $(e,e'p)$ results to constrain the calculation of the direct knockout contribution. Using this approach, a comparison of the ^{209}Bi$(\gamma,p)^{208}$Pb data to various calculations with and without meson exchange contributions shows that the enhancement of the (γ,p) cross section due to meson exchange is small. This is in contrast to results obtained for light nuclei, but in agreement with results for heavier nuclei.

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INTRODUCTION

The $(e,e'p)$ and (γ,p) nuclear reactions have been studied for a number of years, mainly in order to (i) determine single particle bound-state wave functions (BSWF), overlap wave functions and spectroscopic factors and (ii) investigate the role played by meson exchange currents (MEC) in the (γ,p) reaction [1]. Most measurements have been made using even-even nuclei for which the reactions lead to the production of one-hole $(1h)$ and one-particle, two-hole $(1p2h)$ states compared to the target nucleus. The choice of target in many cases was influenced by the availability of detailed (p,p') measurements on the residual nucleus. Ideally, these cover a large range of energies and scattering angles, and include polarization asymmetry determinations. In these cases, the detailed spectrocopic information determined through the $(e,e'p)$ measurements and the optical model parameters obtained from the (p,p') studies are particularly valuable for interpreting the (γ,p) results, since they allow the direct knockout (DKO) contributions to the (γ,p) cross sections to be calculated more accurately than would otherwise be the case and thus permit a more quantitative evaluation of the MEC effects. Of particular interest are measurements on nuclei in the neighborhood of the doubly magic closed shell nuclei ^{16}O, ^{40}Ca, and ^{208}Pb, since these are amenable to the most accurate theoretical calculations.

In this paper, we report first measurements of the ^{209}Bi$(e,e'p)^{208}$Pb and ^{209}Bi$(\gamma,p)^{208}$Pb reactions, which were made at the Nationaal Instituut voor Kernfysica en Hoge-Energiefysica (NIKHEF), Amsterdam, and the MAX-lab, Lund, respectively. These reactions were chosen because they make use of the unique nature of the ^{209}Bi target, which offers the only possibility throughout the periodic table of studying proton knockout reactions leading to a nucleus (^{208}Pb) that has a doubly magic closed shell ground state. This unique feature makes it possible to use a measurement of the hole strength in ^{209}Bi, determined through the $(e,e'p)$reaction, as a way to determine the corresponding particle strength in ^{208}Pb. The idea is based on the fact that the square of the matrix element appropriate for describing the ^{209}Bi$(e,e'p)^{208}$Pb$_{\text{g.s.}}$ reaction (i.e., $\langle ^{208}\text{Pb}_{\text{g.s.}}|a_{nlj}|^{209}\text{Bi}_{\text{g.s.}}\rangle$) is identical to the square of the matrix element describing the particle strength in ^{208}Pb ($\langle ^{209}\text{Bi}_{\text{g.s.}}|a^\dagger_{nlj}|^{208}\text{Pb}_{\text{g.s.}}\rangle$), which can usually only be addressed in stripping reactions. In addition to the ground state being a well understood closed shell, the low lying excited states are equally well understood fairly pure $1p1h$ states of the residual nucleus ^{208}Pb, which make them very suitable for further studies on the remarkable A dependence of MEC in the (γ,p) reaction as presented in Ref. [2]. In this respect, it should be noted that the striking results of Ref. [2] are largely based on the study of one heavy nucleus ^{208}Pb [3].

EXPERIMENTAL METHODS

The ^{209}Bi$(e,e'p)^{208}$Pb experiment [4] was carried out at the EMIN electron scattering facility [5] at NIKHEF-K using electron beam energies of $E_e = 292.5 \pm 0.3$ and 411.8 ± 0.4 MeV. The duty factor and the average beam current were $\sim 0.6\%$ and ~ 1.0 μA, respectively. The target was 195.6 ± 0.5 mg cm^{-2} ^{209}Bi in the form of a metallic foil mounted in a frame which was rotated at ~ 3 Hz. A 34.7 ± 0.1 mg cm^{-2} natural C target was used for energy calibration of the system. The scattered electrons and knocked-out protons were detected in coincidence in two high-resolution magnetic spectrometers with solid angles of 5.54 and 15.9 msr, respectively.

Information on the coincidence detection efficiency and the tuning of the magneto-optical parameters of the spectrometer were obtained using a 15.0 ± 0.5 mg cm^{-2} polyethylene target to study the ^{1}H$(e,e'p)$ reaction. The energy resolution of the ^{209}Bi$(e,e'p)^{208}$Pb reaction was limited to 400–500 keV due to the use of a rather thick target.

Data were accumulated in parallel kinematics (i.e., the momentum of the outgoing proton **p** is closely parallel to the momentum transferred by the virtual photon **q**). The kinematic conditions were chosen to optimize the observation of electron-induced proton knockout from valence shells, especially the transition to the ground state (g.s.) of the ^{208}Pb nucleus. To achieve this, a series of five measurements was carried out in the missing-momentum range $p_m = 110$–290 MeV/c, where $p_m = p' - q$. This range spans the peak in the cross section for the $1h_{9/2}$ transition at $p_m \sim 200$ MeV/c [4]. The knocked-out protons were selected to have energies centered around $T_p = 100$ MeV.

The ^{209}Bi$(\gamma,p)^{208}$Pb experiment was carried out using the tagged photon facility of the MAX-lab [6] at the University of Lund in conjunction with a detector arrangement that was very similar to ones that we have reported on previously [7,8]. Bremsstrahlung radiation was generated using 50 μm thick Al radiators in conjunction with an electron beam of energy $E_e = 75$ MeV. The use of 64 plastic scintillators in the focal plane of the tagging spectrometer gave tagged photons with an energy resolution of $\Delta E_\gamma \sim 330$ keV. The focal plane was divided in two halves which gave mean tagged photon energies of $E_\gamma \sim 43.7$ and ~ 52.0 MeV. Tagged photon rates were $\sim 3 \times 10^6$ photons s^{-1}.

A 50.1 ± 0.5 mg cm^{-2} 99.97% pure Bi foil supported by a 66.1 ± 0.5 mg cm^{-2} polyethylene teraphalate film was placed at $20.0° \pm 0.5°$ to the photon beam direction. Knocked out protons were detected in two solid state detector telescopes developed by the nuclear physics group of Edinburgh University. Each telescope consisted of two Si strip detectors and a HpGe detector which measured the in-plane emission angles and proton energies, respectively. In total, the telescopes covered the angular range $\theta_p = 50°$–$130°$ and subtended a solid angle of ~ 500 msr.

As a check on the performance of the system, calibration runs were made using a C target at intervals throughout the experiment. Measurements were also made with a blank polyethylene teraphalate supporting foil to assist the analysis. The overall excitation-energy resolution of the system was $\Delta E_x \sim 500$ keV.

EXPERIMENTAL RESULTS AND ANALYSIS

We first consider the results of the ^{209}Bi$(e,e'p)^{208}$Pb measurement. The observed spectrum of states excited in ^{208}Pb exhibits two strong peaks corresponding to the population of groups of states at $E_x \sim 4.1$ and ~ 5.4 MeV as shown for $p_m = 150$–210 MeV/c in Fig. 1(a). It is observed in hadron induced proton pickup reactions [9,10] that these two groups of states have widths of $\Delta E_x \sim 500$ keV and appear to arise from the fragmented strength associated with configurations $(\pi[1h_{9/2},(3s_{1/2})^{-1}]$ and $\pi[1h_{9/2},(2d_{3/2})^{-1}])$ and $(\pi[1h_{9/2},(1h_{11/2})^{-1}]$ and $\pi[1h_{9/2},(2d_{5/2})^{-1}])$, respectively. The achieved excitation-energy resolution of $E_x \sim 450$ keV was adequate to resolve these two groups. Statistically significant numbers of counts

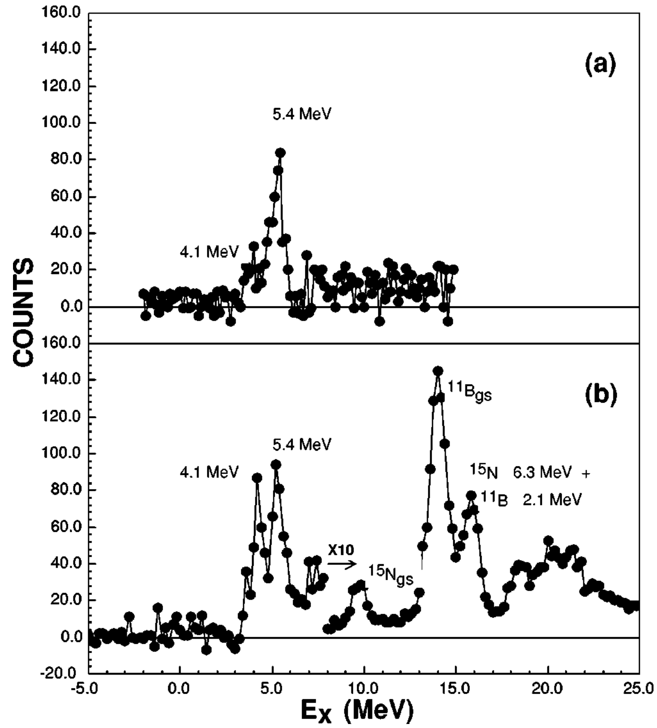

FIG. 1. (a) Experimental excitation-function for the ^{209}Bi$(e,e'p)^{208}$Pb reaction obtained over the missing-momentum range $p_m = 150$–210 MeV/c (central $p_m \sim 180$ MeV/c). (b) Experimental excitation-function for the ^{209}Bi$(\gamma,p)^{208}$Pb reaction obtained at a mean $E_\gamma \sim 48$ MeV, which corresponds to an average $p_m \sim 280$ MeV/c.

from protons populating the isolated ground state were observed in spectra covering certain selected p_m ranges. A significant population of the 2.613 MeV state was not observed.

Reduced cross sections, which are defined as the sixfold differential cross sections divided by the off-shell electron-proton cross section σ^{ep}_{cc1} as given by de Forest [11] and appropriate kinematical factors, were determined from the data [4]. Accidental coincidences were subtracted, phase space corrections made and the spectra unfolded to remove the effects of radiative processes using the methods described by den Herder *et al.* [12]. Missing momentum distributions were obtained from the reduced cross section data by selecting events associated with three different regions in the excitation-energy spectra. The results for the ^{209}Bi$(e,e'p)^{208}$Pb reaction leading to the ^{208}Pb ground state, 4.1 MeV group and 5.4 MeV group are shown in Figs. 2, 3 and 4, respectively.

The missing-momentum distributions were compared to momentum distributions for proton orbits in ^{209}Bi that were calculated using the distorted wave impulse approximation code of Giusti *et al.* [13], which includes distortions of both the electron and proton waves (CDWIA). These calculations were based on Woods-Saxon bound-state wave functions, which were generated using a potential well with parameters taken from Refs. [14–16]. The outgoing-proton distortions were accounted for phenomenologically by the inclusion of an optical-model potential with parameters taken from Ref. [17]. The resulting momentum distributions are shown in

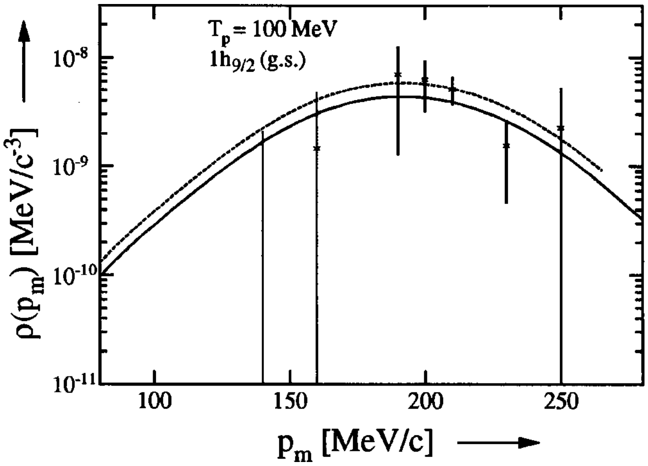

FIG. 2. The missing-momentum distribution for the transition to the ^{208}Pb ground state observed using the reaction ^{209}Bi$(e,e'p)^{208}$Pb. The dashed line is the CDWIA prediction for the DKO of a single proton in the $1h_{9/2}$ orbital. The solid line was obtained by normalizing this curve to the data.

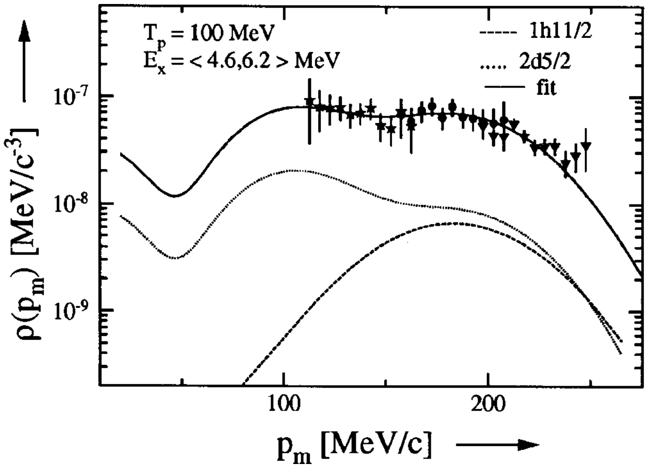

FIG. 4. The missing-momentum distribution for the transitions to the group of states in ^{208}Pb at $E_x\sim 5.4$ MeV observed using the reaction ^{209}Bi$(e,e'p)^{208}$Pb. The dashed and dotted lines are the CDWIA predictions for the DKO of a single proton in (a) the $1h_{11/2}$ orbital and (b) the $2d_{5/2}$ orbital, respectively. The normalizations of (a) and (b) were adjusted independently to give the solid line, which is the best fit of the sum of (a) and (b) to the data.

Figs. 2–4. The dotted and dashed curves are plotted with a normalization that corresponds to one proton being present in a given orbital. The solid lines are least-squares fits to the data in which the normalizations of the contributing orbitals were allowed to vary freely and independently. Reduced spectroscopic factors S were obtained from the normalizations N using the equation $N=(2j+1)S$, where j is the angular momentum of the single particle orbit. These results are shown in Table I and compared to results for the ^{208}Pb$(e,e'p)^{207}$Tl reaction obtained by Bobeldijk *et al.* [8] from a combined analysis of earlier data [18] at low missing-momentum and their high missing-momentum data.

In the single-particle shell model, the nucleus ^{209}Bi is described as a $1h_{9/2}$ proton orbiting an inert ^{208}Pb core. The missing-momentum distribution shown in Fig. 2 is observed to peak at the maximum expected for DKO of a $1h_{9/2}$ proton and thus provides support for this model. The $(2j+1)S$ result obtained for $1h_{9/2}$ proton knockout (0.75 ± 0.18) is consistent with the naive shell-model expectation of unity. However, it is the deviation from unity that makes this transition so interesting. Under the reasonable assumptions [19,20] that (i) the particle and hole strength should add up to unity and (ii) all $1h_{9/2}$ hole strength is located in the ground state transition, we can convert the result given above to an estimate of the particle strength in ^{208}Pb of 1–0.75(18) = 0.25(0.18). If we add this number to the discontinuity Z of the Fermi surface, such as reported in Refs. [18,21], we find a total hole strength for ^{208}Pb of $n(h)=Z+n(p)=0.56(6)+0.25(18)=0.81(19)$. Although the present data are not yet of sufficient precision to make definitive statements, the result is consistent with theoretical estimates of hole strengths in ^{208}Pb of typically 0.7–0.8 [19,20]. More precise data are needed to verify this independent measurement of particle and hole strength in the $A=208$ domain.

As stated earlier, the excited groups of states at 4.1 and 5.4 MeV most likely correspond to the fragmented strength

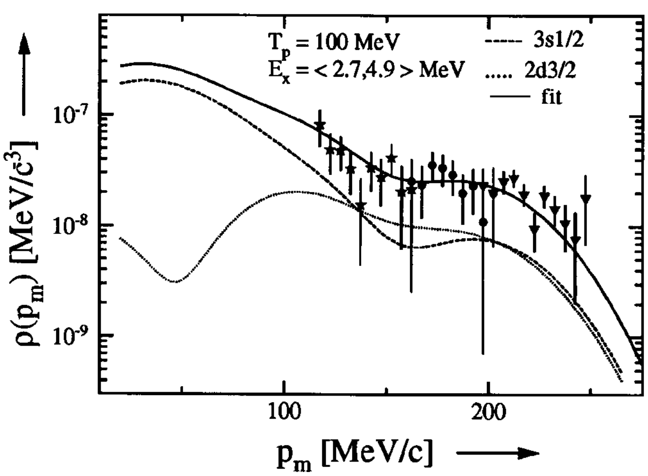

FIG. 3. The missing-momentum distribution for the transitions to the group of states in ^{208}Pb at $E_x\sim 4.1$ MeV observed using the reaction ^{209}Bi$(e,e'p)^{208}$Pb. The dashed and dotted lines are the CDWIA predictions for the DKO of a single proton in (a) the $3s_{1/2}$ orbital and (b) the $2d_{3/2}$ orbital, respectively. The normalizations of (a) and (b) were adjusted independently to give the solid line, which is the best fit of the sum of (a) and (b) to the data.

TABLE I. Reduced spectroscopic factors determined using the ^{209}Bi$(e,e'p)^{208}$Pb and ^{208}Pb$(e,e'p)^{207}$Tl reactions.

Hole excitation in ^{208}Pb	^{209}Bi$(e,e'p)^{208}$Pb	^{208}Pb$(e,e'p)^{207}$Tl
	This work	Bobeldijk *et al.* [21]
Ground state ($1h_{9/2}$)	0.075 ± 0.018	
$3s_{1/2}$	0.68 ± 0.50	0.55 ± 0.06
$2d_{3/2}$	0.42 ± 0.26	0.57 ± 0.05
$1h_{11/2}$	0.62 ± 0.10	0.58 ± 0.06
$2d_{5/2}$	0.44 ± 0.08	0.54 ± 0.04

associated with configurations ($\pi[1h_{9/2},(3s_{1/2})^{-1}]$ and $\pi[1h_{9/2},(2d_{3/2})^{-1}]$), and ($\pi[1h_{9/2},(1h_{11/2})^{-1}]$ and $\pi[1h_{9/2},(2d_{5/2})^{-1}]$), respectively. This interpretation is supported by the good fits to the data shown in Figs. 3 and 4, which are based on the DKO of protons from appropriate orbits in the ^{208}Pb core. In addition, it is observed from Table I that the spectroscopic factors agree within errors with results obtained using the ^{208}Pb$(e,e'p)^{207}$Tl reaction. The large errors associated with the $3s_{1/2}$ and $2d_{3/2}$ spectroscopic factors obtained from this work arise due to the fact that the fitting procedure was not very sensitive to the relative contributions from each orbital. It should be noted, however, that the summed strength for both states ($N_1+N_2=3.06\pm0.48$) has a smaller overall error and agrees quite well with the summed strength (3.36 ± 0.36) observed in the ^{208}Pb$(e,e'p)^{207}$Tl reaction. In view of all the above results, it would appear that a model of ^{209}Bi based on a $1h_{9/2}$ proton orbiting an inert ^{208}Pb core has a high degree of validity.

We now consider the ^{209}Bi$(\gamma,p)^{208}$Pb results. From Fig. 1(b), it is observed that in the low ^{208}Pb excitation region, the reaction populates most strongly the two groups of states at $E_x\sim4.1$ and ~5.4 MeV. However, the relative population of these states is quite different from that observed using the ^{209}Bi$(e,e'p)^{208}$Pb reaction, as discussed below. Statistically significant numbers of counts from protons populating the isolated ground and 2.613 MeV states were not observed, as expected from counting rate estimates based on the ^{209}Bi$(e,e'p)^{208}$Pb results.

The strongest peaks in the (γ,p) excitation spectrum originated from reactions on ^{12}C and ^{16}O in the supporting foil leading to well known states in the residual nuclei ^{11}B and ^{15}N, as indicated in Fig. 1(b). Data from the ^{12}C$(\gamma,p_0)^{11}$B$_{\text{g.s.}}$ channel were analyzed and used in conjunction with the well known cross section results [22] to determine the detection efficiency of the system as a function of detection angle θ_p. These data were used to establish the absolute cross sections for the ^{209}Bi$(\gamma,p)^{208}$Pb reaction as a function of θ_p at the two mean γ energies $E_\gamma\sim43.7$ and ~52.0 MeV. The results, together with comparable results for the ^{208}Pb$(\gamma,p)^{207}$Tl reaction [8,2], are shown in Figs. 5 and 6, respectively. Only statistical errors are shown. The systematic uncertainties in the absolute cross sections were estimated to be $\pm10\%$, which arise mainly from the absolute errors associated with ^{12}C$(\gamma,p_0)^{11}$B$_{\text{g.s.}}$ results [22] used to determine the detection efficiency.

To interpret the new (γ,p) results, we first consider the fact that the relative population of the 4.1 and 5.4 MeV groups are different for the ^{209}Bi$(\gamma,p)^{208}$Pb and ^{209}Bi$(e,e'p)^{208}$Pb reactions, and the ratio varies quite strongly with angle or equivalently p_m. The relative strengths of the two groups of states observed using the (γ,p) reaction develop with increasing p_m oppositely to what would be expected on the basis of the momentum distributions measured using the $(e,e'p)$ reaction. From Figs. 3 and 4, it is seen that the DKO strength for the 4.1 MeV peak decreases more steeply with p_m than the 5.4 MeV peak, which would lead to an even larger difference than is observed between the two peaks in the higher p_m domain

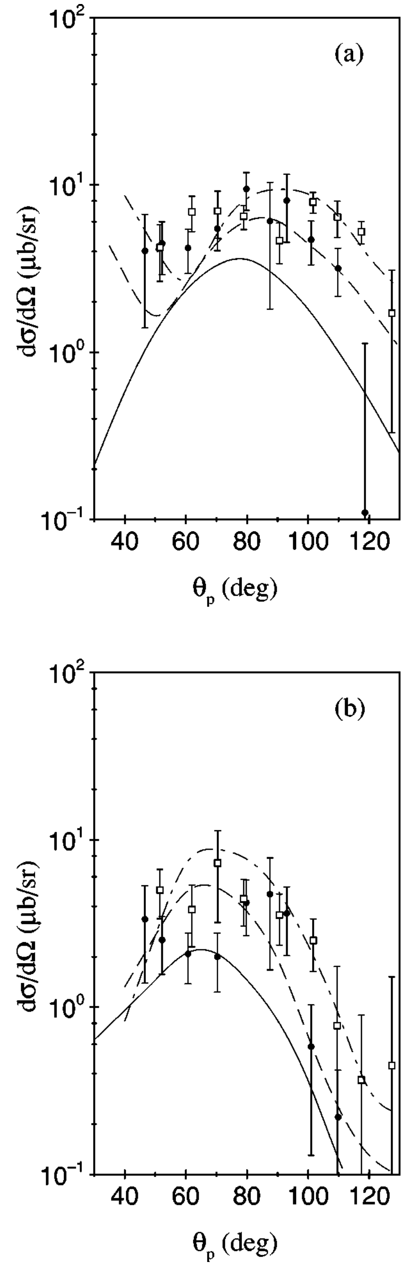

FIG. 5. Differential cross sections for the ^{209}Bi$(\gamma,p)^{208}$Pb reaction leading to the 4.1 MeV ($\pi[1h_{9/2},(3s_{1/2})^{-1}]$ and $\pi[1h_{9/2},(2d_{3/2})^{-1}]$) group of states in ^{208}Pb (solid circles), at (a) mean $E_\gamma\sim43.7$ MeV and (b) ~52.0 MeV. Also shown are results for the ^{208}Pb$(\gamma,p)^{207}$Tl reaction leading to the ($\pi[(3s_{1/2})^{-1}]$ and $\pi[(2d_{3/2})^{-1}]$) doublet in ^{207}Tl (open squares) at (a) mean $E_\gamma\sim45$ MeV and (b) ~54 MeV [8]. The theoretical results shown are DKO calculations (solid lines), and the results of RPA calculations without and with MEC (dashed and dot-dashed, respectively) by Ryckebush taken from Ref. [8].

probed by the (γ,p) reaction. In contrast, we see from Figs. 5 and 6 that the two peaks are excited with roughly equal strength in the (γ,p) case. These differences imply that the reaction mechanisms involved in the (γ,p) and $(e,e'p)$ reactions are not the same. While the $(e,e'p)$ measurements can be well understood assuming that the reaction proceeds through a DKO mechanism [2], the (γ,p) reaction may in-

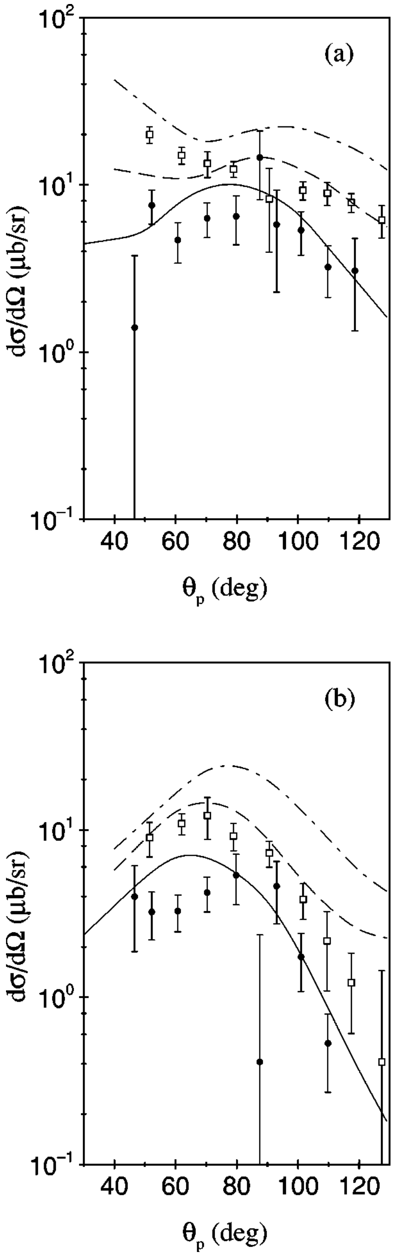

FIG. 6. Differential cross sections for the ^{209}Bi$(\gamma,p)^{208}$Pb reaction leading to the 5.4 MeV $(\pi[1h_{9/2},(1h_{11/2})^{-1}]$ and $\pi[1h_{9/2},(2d_{5/2})^{-1}])$ group of states in ^{208}Pb (solid circles), at (a) mean $E_\gamma \sim 43.7$ MeV and (b) ~ 52.0 MeV. Also shown are results for the ^{208}Pb$(\gamma,p)^{207}$Tl reaction leading to the $(\pi[(1h_{11/2})^{-1}]$ and $\pi[(2d_{5/2})^{-1}])$ doublet in ^{207}Tl (open squares) at (a) mean E_γ ~ 45 MeV and (b) ~ 54 MeV [8]. The theoretical results shown are DKO calculations (solid lines), and the results of RPA calculations without and with MEC (dashed and dot-dashed, respectively) by Ryckebush taken from Ref. [8].

volve other processes as well. It is commonly assumed that the (γ,p) reaction may in addition involve absorption of the photon on pairs of nucleons and be influenced by MEC [23–25].

An additional point to be considered is the fact that the ^{209}Bi$(\gamma,p)^{208}$Pb measurements are on average lower than the ^{208}Pb$(\gamma,p)^{207}$Tl results as shown in Figs. 5 and 6. It should be noted that for these comparisons, the systematic errors of $\pm$ 10% can be largely ignored since the two sets of measurements were made using the same experimental setup. Since MEC effects are sensitive to details of the nuclear structure, the observed differences between the (γ,p) results for ^{209}Bi and ^{208}Pb might originate in a subtle interplay between MEC and nuclear structure effects.

To consider this further, we compared the (γ,p)results to two sets of theoretical calculations performed at the appropriate mean E_γ energies. The first of these were distorted wave impulse approximation calculations (DWIA) based on the DKO model of Boffi *et al.* [26,27]. These calculations incorporated relativistic kinematics, nonlocality corrections for the bound-state wave function, center-of-mass (c.m.) corrections, and orthogonality and antisymmetry corrections. A nonlocality correction was not applied to the proton continuum wave function because, as pointed out by de Forest [28], the orthonormality condition between two wave functions that are solutions of an energy-dependent potential corresponds to a nonlocality correction. The c.m. correction produces recoil terms corresponding to the photon interacting with the residual nucleus. These recoil terms are most important for light nuclei and had a negligible effect on the results presented here. The BSWF parameters, taken from Woods *et al.* [16], were identical to those used in the determination of the spectroscopic factors presented in Table I. The optical model parameters used to account for distortions of the outgoing proton waves were taken from Varner *et al.* [29], who considered $T_p = 10$–60 MeV data from nuclei in the range $A = 40$–209. The spectroscopic factors were taken from the ^{208}Pb$(e,e'p)^{207}$Tl data of Bobeldijk *et al.* [21] as given in Table I. The results of these calculations are shown as solid lines in Figs. 5 and 6.

The second set of calculations we used were carried out by Ryckebusch for the ^{208}Pb$(\gamma,p)^{207}$Tl measurements of Bobeldijk *et al.* [8]. Assuming the ^{208}Pb core is not appreciably perturbed by the presence of the $1h_{9/2}$ proton, these calculations should apply equally to the ^{209}Bi$(\gamma,p)^{208}$Pb reaction. The calculations were performed using a coupled channels approach in the random phase approximation (RPA) according to the models described in Refs. [24,25]. The MEC effects are introduced as photon absorption on two-body currents [8]. The RPA calculations without and including MEC effects are shown as dashed and dash-dotted lines, respectively.

All the calculations describe the shape of the cross section angular distributions reasonably well, suggesting that the reaction involves mainly $E1$ transitions as expected. The DKO curves, however, underestimate the 4.1 MeV group of states, while they are more or less in agreement with the data for the 5.4 MeV group of states. The fact that the DKO curves are relatively close to the data in both cases confirms the findings of Aschenauer *et al.* [2,3], which indicate that MEC effects enhance the (γ,p) cross section in heavy nuclei by only a factor of 2 or less, depending on angle. This is to be compared to enhancement factors (F) of about 10, which were found in light nuclei. It has been suggested by Ryckebusch [30] that the observed reduction of F in going from $A = 12$ to $A = 208$ can be explained by a cancellation of amplitudes that occurs through the destructive interference of many multipoles. This interference will be larger in heavier nuclei due to their larger spatial extent and the higher l values involved.

The above suggestion may also provide a qualitative explanation of the relative cross sections for exciting the 4.1 and 5.4 MeV groups in the ^{209}Bi$(\gamma,p)^{208}$Pb reaction. From Figs. 5 and 6 it is observed that the 4.1 and 5.4 MeV measurements lie slightly above and close to the DKO calculations, respectively. Due to the fact that excitation of the 5.4 MeV group arises from $1h_{11/2}$ and $2d_{5/2}$ proton removal and hence involves larger l values with wave functions peaking at large radii, the destructive interference suggested by Ryckebusch could be sufficient to effectively eliminate the MEC effects and give $F\sim 1$. On the other hand, fewer l multipoles contribute to excitation of the 4.1 MeV group ($3s_{1/2}$ and $2d_{3/2}$ proton removal) with wave functions peaking at smaller radii. This could explain why MEC effects appear to be larger for that group, albeit at a moderately low level corresponding to $F\sim 2$. The relative enhancement of the RPA calculations due to MEC effects does not show a difference between the two groups of states, and in general gives rise to calculated cross sections that exceed the data. This result suggests that an insufficient number of partial waves (l values) has been included in the calculation.

CONCLUSION

Results have been presented for the ^{209}Bi$(e,e'p)^{208}$Pb and ^{209}Bi$(\gamma,p)^{208}$Pb reactions for the first time. It is observed that whereas the $(e,e'p)$ reactions involving the same ^{208}Pb hole states exhibit similar cross sections, the (γ,p) cross sections are quite different. The $(e,e'p)$ results can be explained assuming (i) a DKO mechanism and (ii) the ^{208}Pb core of ^{209}Bi is not appreciably perturbed by the $1h_{9/2}$ valence proton. The ^{209}Bi$(e,e'p)^{208}$Pb results have been used to study the amount of particle strength in the $A=208$ region. The result found (0.25 ± 0.18) is consistent with the theoretical expectations, but not yet sufficiently precise. The different behavior observed for the ^{209}Bi$(\gamma,p)^{208}$Pb reaction is attributed to additional reaction mechanisms involving photon absorption on nucleon pairs and MEC effects. The enhancement of the cross section with respect to the corresponding DKO calculation amount to $F\sim 2$ and $F\sim 1$ for the 4.1 and 5.4 MeV groups, respectively. These results are comparable to those obtained for other heavy nuclei. The very small $F\sim 1$ value obtained for the 5.4 MeV group provides additional evidence for the observation of Aschenauer *et al.* on reduced MEC effects in the reaction (γ,p) on heavy nuclei.

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