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TITLE: A DEPENDENCE OF THE EXCITATION ENERGY, WIDTH, AND CROSS SECTION OF THE ISOVECTOR MONOPOLE RESONANCE

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A DEPENDENCE OF THE EXCITATION ENERGY, WIDTH, AND CROSS SECTION  
OF THE ISOVECTOR MONOPOLE RESONANCE

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We have used the  $(\pi^-, \pi^0)$  charge-exchange reaction at 165-MeV kinetic energy to study the  $T + 1$  component of the isovector monopole resonance (IVM). The nuclei  $^{40}\text{Ca}$ ,  $^{60}\text{Ni}$ ,  $^{90}\text{Zr}$ ,  $^{120}\text{Sn}$ ,  $^{140}\text{Ce}$ , and  $^{208}\text{Pb}$  were used as targets. We also observed the  $T + 1$  component of the giant dipole resonance (GDR) in the lighter targets. The  $(\pi^+, \pi^0)$  reaction also yielded positive results for the  $T - 1$  component of the IVM and GDR in  $^{40}\text{Ca}$ ,  $^{60}\text{Ni}$ , and  $^{90}\text{Zr}$ .

Pion charge exchange is well suited to the study of isovector giant resonance and particularly the IVM for a number of reasons. The pion is spinless and at forward angles the excitation of spin-flip states is strongly inhibited. The charge-exchange reactions proceed through the  $T \cdot \tau$  piece of the  $\pi$  nucleon  $t$  matrix and hence charge-exchange reactions must excite isovector states. This is in contrast to inelastic hadron scattering which strongly excites isoscalar states. Giant resonances have large transition densities in the nuclear surface. Since 165-MeV  $\pi$ 's are strongly absorbed, they couple efficiently to these surface-peaked transition densities. This point is crucial for monopole modes where the volume integral of the transition density vanishes. The excitation of a monopole mode by a weakly absorbed probe is therefore strongly suppressed at forward angles. The angular distributions produced by the strongly absorbed 165-MeV  $\pi$ 's are sharply diffractive and allow a direct determination of the angular momentum of the final states. Finally, the Coulomb energy shifts the  $T + 1$  component of the IVM to a low-excitation energy in the  $(\pi^-, \pi^0)$  daughter nucleus. The decay width of this state is therefore reduced.

Figure 1 shows plots of double-differential cross sections for the  $(\pi^-, \pi^0)$  reaction vs the kinetic energy of the detected  $\pi^0$ 's. Representative targets  $^{60}\text{Ni}$  and  $^{140}\text{Ce}$  are shown. The top spectra have a scattering angle of  $4^\circ$  near the forward direction where the IVM cross section is largest. The middle spectra have a scattering angle of  $15^\circ$  where the IVM cross section is small and that of the GDR is

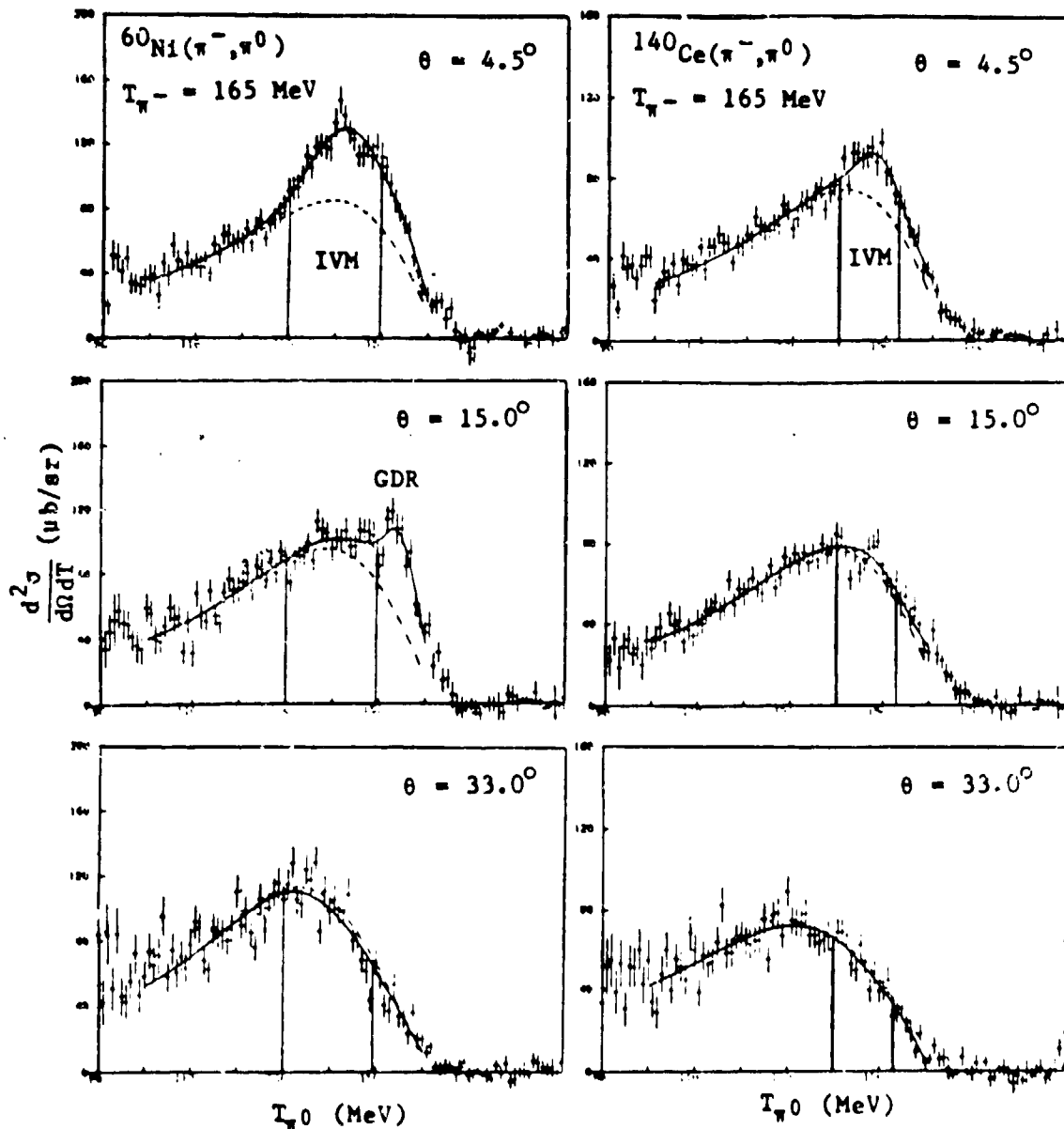
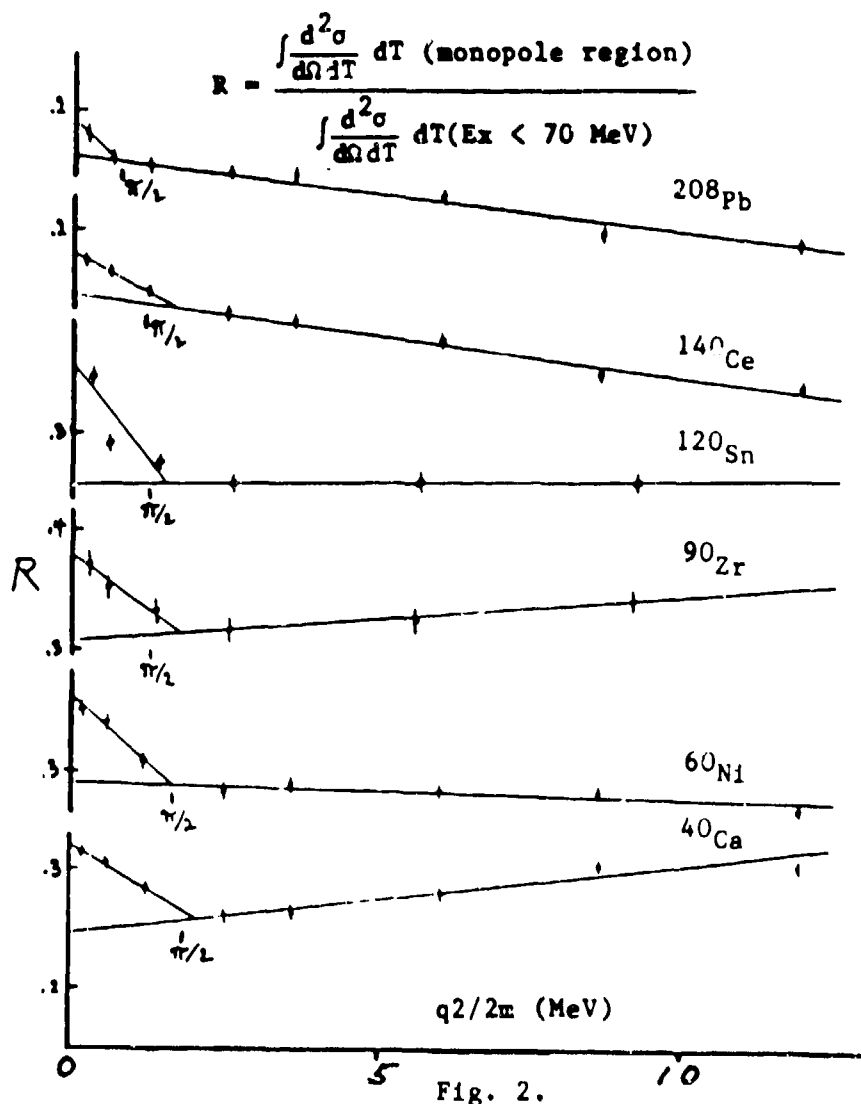


Fig. 1.

largest. The bottom spectra are at  $33^\circ$  where both the IVM and GDR have small cross sections. The dashed lines represent a smoothly interpolated background. In Fig. 2 we plot the normalized cross section  $R$  in the monopole region of the spectra section  $R$  in the monopole region of the spectra vs momentum transfer squared ( $q = k_\pi \sin \theta$ ). The monopole-region cross sections were divided by the observed differential cross section

$$R = \frac{\int \frac{d^2\sigma}{d\Omega dT} dT \text{ (monopole region)}}{\int \frac{d^2\sigma}{d\Omega dT} dT \text{ (Ex < 70 MeV)}}$$

It is the excess of cross section above the linearly extrapolated background that we identify as due to the IVM. The first minimum of the IVM angular distribution



occurs where  $qR = 1/2 \pi$ , where  $R$  is the  $\pi$  absorption radius. This point is indicated on Fig. 2. The observed break points between the background and the forward-peaked IVM feature are near the  $1/2 \pi$  point for each nucleus.

Angular distributions, excitation energies, and widths were extracted by fitting the double-differential cross sections to a sum of IVM, GDR, and nonresonant background components. The background was smoothly interpolated under the resonances as a function of  $q^2$  and  $T_{\pi 0}$ . The angular distribution for the IVM and GDR peaks in the  $^{60}\text{Ni}(\pi^-, \pi^0)$  data are shown in Fig. 3. The solid lines are the angular distribution of Auerbach and Klein<sup>1</sup> normalized to the data. In Fig. 4 we show the ratio of fitted maximum monopole and dipole cross sections to the calculations of Auerbach and Klein for the different targets. The dipole and monopole ratios agree to within the statistical errors except for the  $(\pi^+, \pi^0)$   $^{140}\text{Ce}$  and  $^{208}\text{Pb}$  data where the nonresonant background is large, leading to large systematic errors in the decomposition of the spectra. In Fig. 5 we show excitation

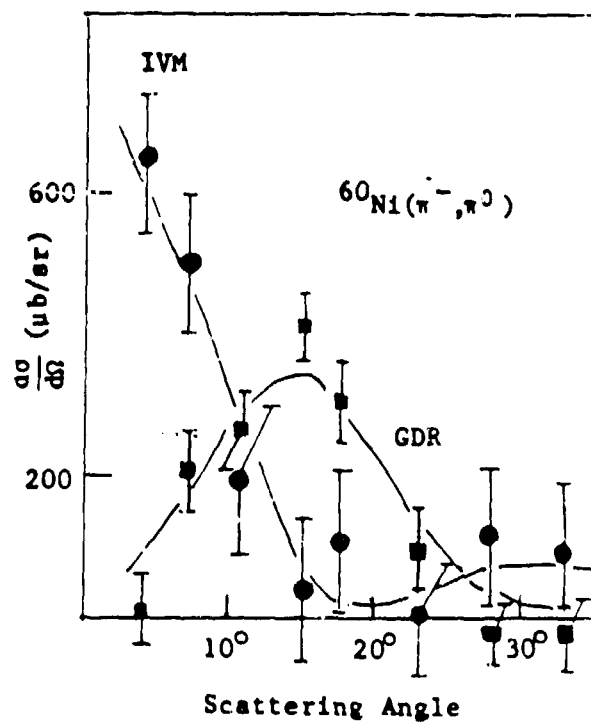


Fig. 3.

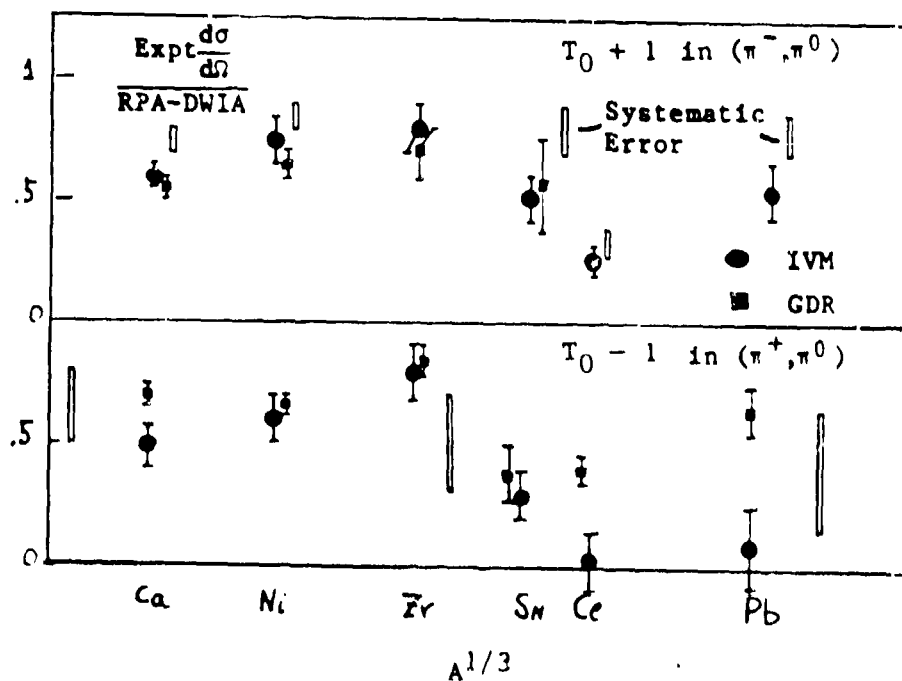


Fig. 4.

energies and widths again compared to the RPA theory of Auerbach and Klein. The agreement is remarkable.

We observed no hint of isovector quadrupole signal. For example, in the  $^{60}\text{Ni}(\pi^-, \pi^0)$  data where we observe 70% of the IVM and GDR cross sections predicted by the RPA-DWIA theory, we observe <25% (90% confidence) of the isovector quadrupole predicted cross section.

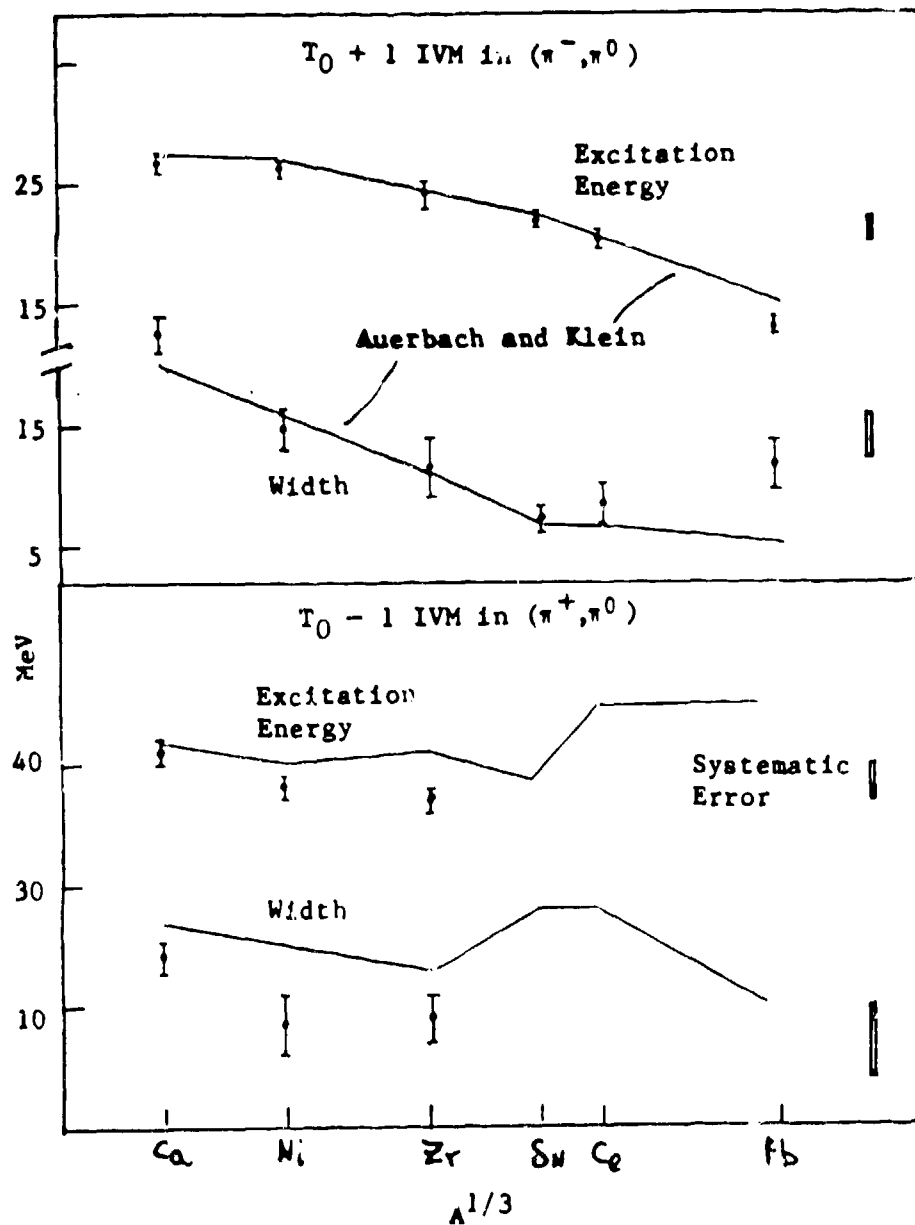


Fig. 5.

Our conclusions are: The IVM is a systematic feature of nuclei from  $^{40}\text{Ca}$  to  $^{208}\text{Pb}$ . Its excitation energy and width are well reproduced by RPA calculations. Its cross section is large, indicating the collective nature of the state, and is in qualitative agreement with RPA-DWIA theory. The IVM and GDR cross sections deviate from RPA-DWIA theory by the same ratio. The absence of the isovector quadrupole resonance poses an interesting problem.

#### REFERENCE

1. N. Auerbach and A. Klein, this conference proceedings.