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ALPHA DECAY OF THE GIANT QUADRUPOLE RESONANCE IN ^{238}U.

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A B S T R A C T

Evidence for the alpha decay of the Giant Quadrupole Resonance is reported. Measurements of the reaction $^{38}U(e,e',\alpha)^{234}Th$ in the region 9 - 24 MeV are presented. The results imply that the reaction goes dominantly through *E2* absorption. The amount of *E2* strength used by the alpha emission channel exausts 50 per cent of the isoscalar energy weighted sum rule.

S U M A R I O

São apresentadas evidências de que a Ressonância Gigante de Quadrupolo decai por emissão alfa. São apresentadas medidas da reação $^{238}U(e,e',\alpha)^{234}Th$ na região 9 - 24 MeV. Os resultados mostram que a reação procede dominantemente através de absorção *E2*. O canal de emissão alfa gasta 50% da regra da soma ponderada em energia aplicada a transições *E2*, isoescalares.

It has been recently suggested that the study of (γ,α) and (α,γ) reactions could reveal interesting features of the Giant Quadrupole Resonance, GQR, since in these reactions the effects of the isovector giant dipole resonance, GDR, are supressed[1]. In this letter, evidence that the Giant Quadrupole Resonance, GQR, decays strongly by alpha emission is presented.

The GQR has been extensively studied by electron and hadron scattering. From these measurements it is possible to observe the strength of quadrupole absorption by the nucleus.

While for the dipole absorption the dominant mode of decay of the GDR is by neutron emission and fission, no measurements have been reported on the decay modes of the GQR.

The electrodisintegration cross section by emission of a particle x (integrated over all scattering angles), $\sigma_{e,x}(E_o)$ is related to the corresponding photodisintegration cross section, $\sigma^{\lambda L}_{\gamma,x}(E)$, through:

$$\sigma_{e,x}(E_o) = \int_0^{E_o} \sum_{\lambda L} \sigma^{\lambda L}_{\gamma,x}(E)\, N^{\lambda L}(E_o,E)\, \frac{dE}{E} \qquad (1)$$

where E_o is the electron bombarding energy, E is the photon energy, $N^{\lambda L}$ is the virtual photon spectrum, and $\sigma^{\lambda L}_{\gamma,x}$ is the cross section for photodisintegration through a nuclear transition of multipolarity λL.

Gargaro and Onley[2] have obtained computable expressions for $N^{\lambda L}$ using distorted wave approximation and the agreement with experimental results has been shown by Nascimento et al.[3] and Wolynec et al.[4,5].

If we know, that in the energy region under study there are one or two dominant multipoles in the absorption, then the sum in expression (1) reduces to one or two terms and by measuring the electrodisintegration cross section it is possible to obtain the multipolarity of the transitions involved in the photodisintegration.

Since the quadrupole component of virtual photons is one order of magnitude larger than the dipole for high Z (see fig. 1), while real plane wave photons have all multipole components in equal amounts, the relative magnitude of the cross section for the quadrupole to the dipole mode is greatly enhanced for electrons as compared to photons, the enhancement being greater the higher the Z of the target nucleus[3].

The above considerations led us to choose (e, e', α) reactions and ^{238}U as our first candidate for the study of the decay of the GQR through alpha emission.

Very thin Uranium targets (thickness of the order of 10^{-5} radiation lengths, R.L.) were bombarded in the electron linear accelerator of Universidade de São Paulo. The amount of ^{238}U in the targets was determined by alpha spectroscopy. Prior to bombardment the natural activity of the 63 KeV gamma ray line, from the decay of ^{234}Th to ^{234}Pa was counted in a Ge-Li low energy photon spectrometer. As the half life of this decay is 24.1 days, ^{234}Th is in radioactive equilibrium with ^{238}U and the activity of that gamma ray line is proportional to the ^{238}U alpha activity. After irradiation the 63 KeV line activity was measured in the same counter and geometry. The previously determined contribution associated with spontaneous alpha emission was subtracted as background.

In fig. 2 the experimental cross section for the reaction ^{238}U$(e,e',\alpha)^{234}$Th, as a function of electron incident energy, is shown as full circles. Below 9 MeV the cross section was too small to be measured. The main contribution to the errors indicated comes from the subtraction of the natural activity that typically amounted to 70% of the activity after irradiation.

We have also measured the yield for electron plus bremsstrahlung induced alpha emission, $\sigma_{e,\alpha}+\sigma_{br,\alpha}$. For these measurements a 0.01 R.L. Aluminum radiator was placed in front of the targets. As shown in fig. 2, within experimental errors, there is no difference between the values obtained for $\sigma_{e,\alpha}$(full circles) and $\sigma_{e,\alpha}+\sigma_{br,\alpha}$(triangles). This behaviour is typical of an *E2* process. If alpha emission ocurred dominantly through *E1* absorption, the expected values for $\sigma_{br,\alpha}$ are of the same magnitude as $\sigma_{e,\alpha}$ and consequently $\sigma_{e,\alpha}+\sigma_{br,\alpha}$ would be about twice the value for $\sigma_{e,\alpha}$[4,5].

The amount of quadrupole strength absorbed by the nucleus and used for alpha emission can be estimated by evaluating the integral of expression (1) with only the *E2* virtual photon kernel and an assumed cross section for $\sigma^{E2}_{\gamma,\alpha}(E)$.

As an approximation we represented $\sigma_{\gamma,\alpha}$ by a Breit-Wigner of area A, width Γ and peak position E_p. In fig.2 the best fit to experimental data, obtained for A = 28 MeV.mb, Γ = 3.7 MeV and E_p = 8.9 MeV, is shown as curve labelled *E2*. The cross section was supposed to vanish below 6 MeV since only above this value alpha emission competes favorably against gamma deexcitation[6].

The strong dependence of the χ^2 of the fit on the values of A, E_p and Γ indicates the sensivity of the method. At the 95% confidence level our results can be stated as A = 28 $\pm$ 3 MeV.mb, Γ = 3.7 $\pm$ 1.2 MeV and E_p = 8.9 $\pm$ 0.3 MeV.

From the above results we conclude that the amount of absorbed *E2* strength used for the (γ,α) reaction exausts 50 $\pm$ 5 per cent of the isoscalar energy weighted sum rule EWSR [7]. The (γ,α) cross section is concentrated around 9 MeV, which is compatible with the location at $58/A^{1/3}$MeV, predicted by Bohr and Mottelson[8] for the isoscalar giant quadrupole resonance.

The curve labelled σ_{br} in fig.2 is the predicted bremsstrahlung yield with our radiator inserted, assuming a quadrupole resonance with the parameters given above. The small magnitude of this result explains why we were unable to detect any difference in the yields with and without radiator.

Curve labelled *E1* in fig.2 is the predicted yield curve for a pure *E1* process. In order to obtain a yield curve of the same magnitude as the experimental results, it would be necessary to assume a Breit-Wigner shape with A = 600 MeV.mb (more than half the integrated cross section for $\sigma_{\gamma,n}$) which is unrealistic and incompatible with our experimental results taken with a radiator.

Summarizing, we have measured the cross section for the reaction $^{238}U(e,e',\alpha)^{234}Th$ and shown that our results can be explained on the basis of a pure *E2* process, exausting 50% of the isoscalar EWSR. We have corroborated the suppression of alpha emission through excitation of the GDR. These results, associated with the strong enhancement of *E2* excitation by electrons, establishes (e,e',α) reactions as a sensitive detector for the experimental study of the GQR.

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FIGURE CAPTIONS

Fig. 1 - Electric dipole and quadrupole virtual photon spectra for electrons of kinetic energy 24.5 MeV, scattered by a uranium nucleus.

Fig. 2 - Experimental cross section for the reaction $^{238}\mathrm{U}(e,e',\alpha)^{234}\mathrm{Th}$ (circles), versus electron kinetic energy. The triangles refer to the experimental yield for the same reaction induced by electron plus bremsstrahlung. The labelled curves are the calculated values (Breit-Wigner parameters indicated) for: the bremsstrahlung yield (curve σ_{br}); the cross section for (e,e',α) in the cases of a pure *E2* process (curve E2) and a pure *E1* process (curve E1).

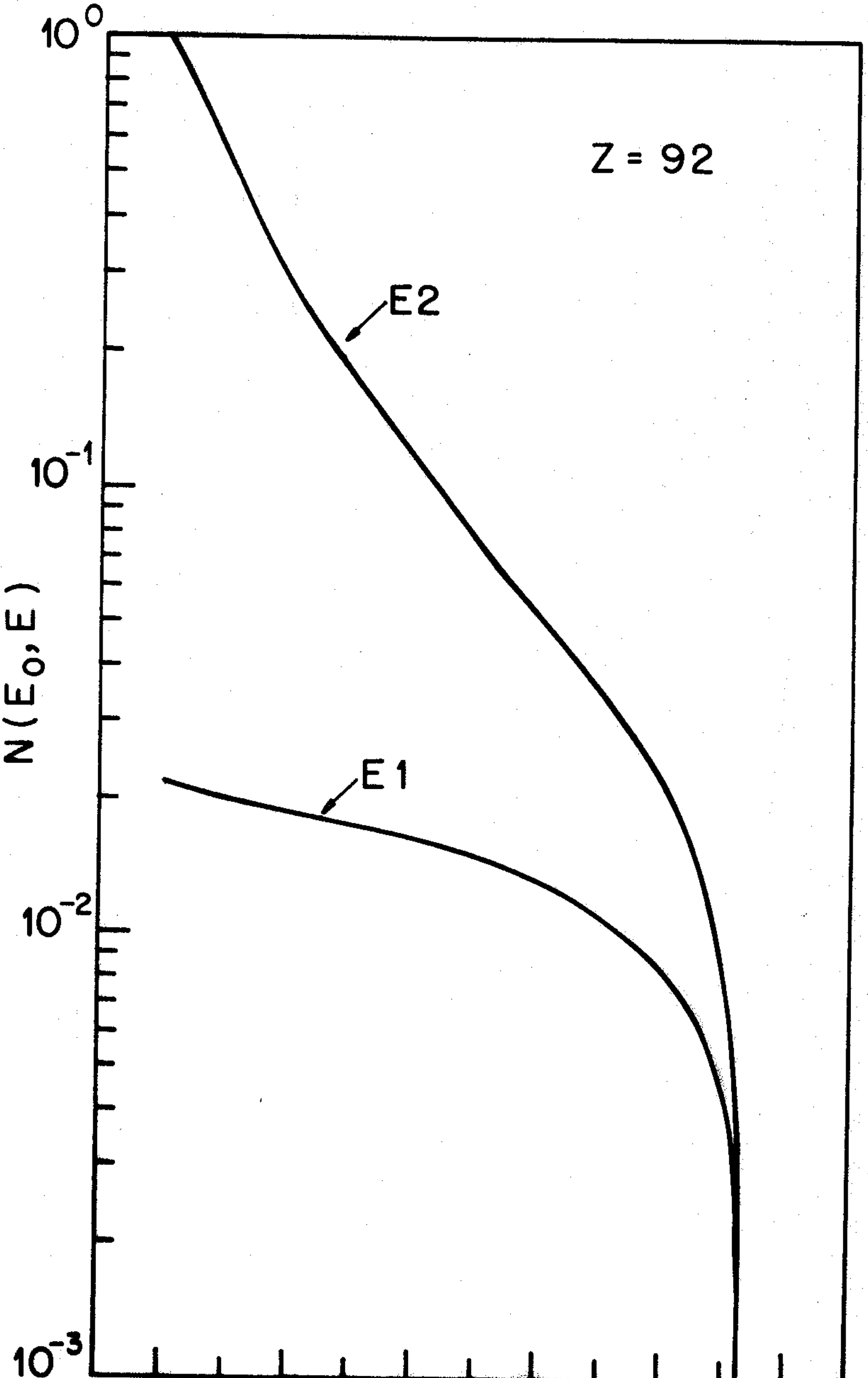
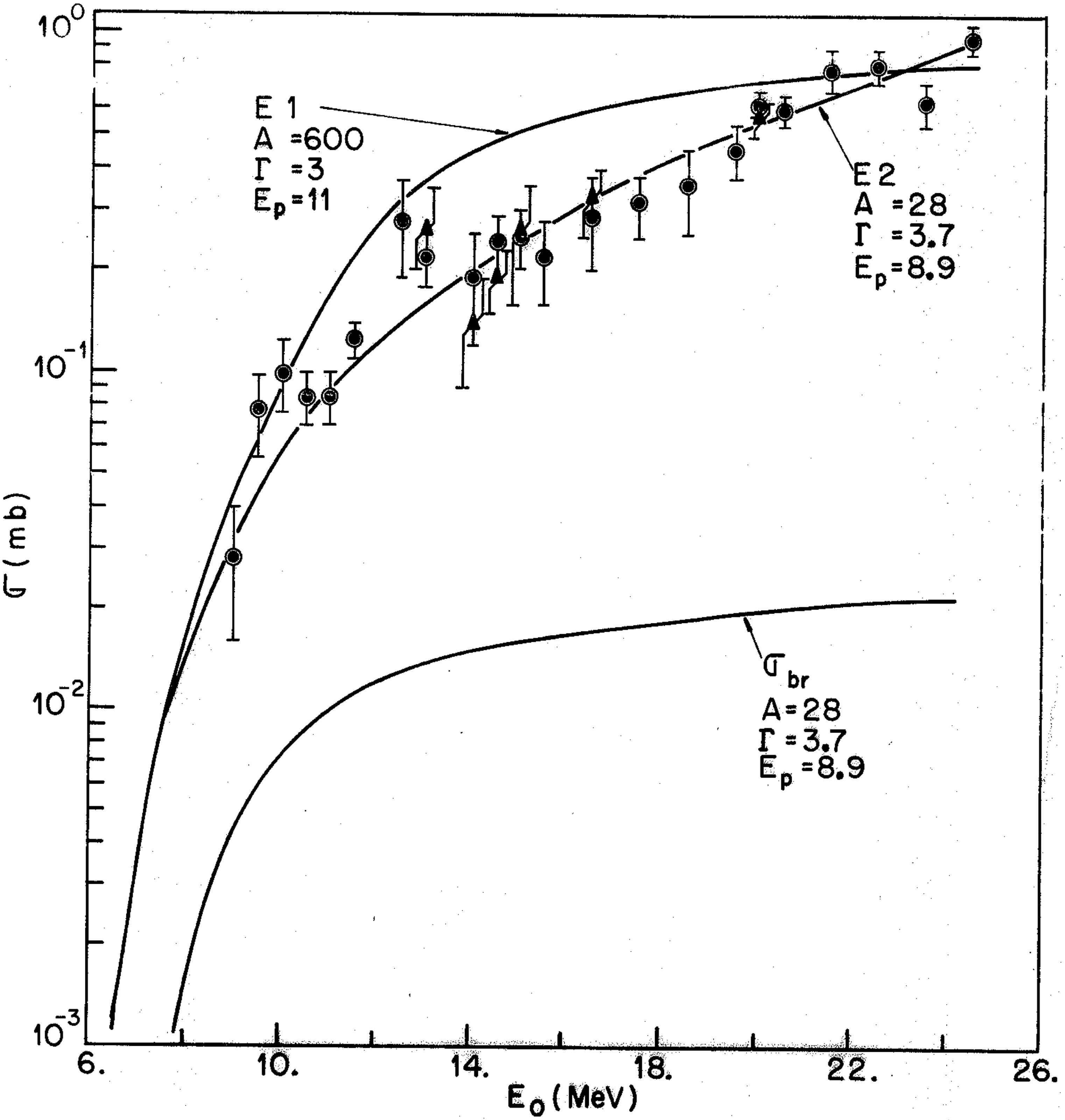


Fig. 1



10^0
10^{-1}
10^{-2}
10^{-3}
σ (mb)
E 1
A =600
Γ =3
E_p=11
E 2
A =28
Γ =3.7
E_p=8.9
σ_{br}
A=28
Γ=3.7
E_p=8.9
6.
10.
14.
18.
22.
26.
E_0 (MeV)

Fig. 2