Giant Resonance Study by Proton Inelastic Scattering at and near Zero Degrees

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The mean excitation energy of the isoscalar giant monopole resonance (GMR) is related to nuclear incompressibility. Inelastic scattering at extremely forward angles including 0° is very useful for studying the $\Delta L = 0$ collective states. Until recently, studies of GMR using proton inelastic scattering were categolized to be difficult. However, the recent new installation of focal plane-polarimeter (FPP)[7] enables us to determine the decomposition of spin-isospin modes [1]. The giant resonance in ^{58}Ni was studied by D. H. Youngblood *et al.* [5] via inelastic scattering of 240 MeV alpha particles at forward angles include 0°, where the peak-to-background ratios were very small. They showed the total GMR stregth in the region $E = 12$ to 25MeV was only a third of the E0 energy weighted sum rule (EWSR) limit.

We have measured proton inelastic scattering from ^{58}Ni (9.86 mg/cm^2) at 0° (cross sections and polarizatrion transfer observables) using two in-plane polarized (∼0.7) proton beams at 394 MeV (2-3 nA) with independent polarization axis, with the Grand Raiden spectrometer [6] and FPP. Horizontal scattering angles are determined by a ray-tracing technique. Vertical angles were not determined in this method due to the ion optical properties of the spectrometer. We defined the vertical acceptance ($|\phi| \leq 28.5$ mr) by the entrance slits of the spectrometer with active scintillator collimaters to avoid background events from edge scattering.

The upper part of Fig. 1 shows a ^{58}Ni(p,p') at 0° spectrum. The energy resolution is 250 keV in full width at half maximum. A broad bump at E=∼ 18 MeV is the superposition of several giant resonances. The resonance peak has a forward-peaking angular distribution. The upper part of Fig.2 shows the total spin transfer Σ, spin-flip and non-spin-flip differential cross sections (hatched region). In the bump region, non-spin-flip resonances dominate because the Σ are small. In order to deduce the GMR strength from the non-spin-flip cross section, we need to subtract the contribution of other possible giant resonances such as the IVGDR and the GQR. Assuming that the E1 EWSR exhausted 100 % and its strength distribution was the same as that of the (e,e') experiment with the multipole decomposition [8], we subtracted the IVGDR cross section from non-spin-flip cross section using the DWBA calculation with macroscopic form factors [2, 3, 4]. We fitted the bump shape by a Lorentzian function with the central energy of 17.6 MeV and the width of 4.4 MeV.

In the next step, we now assumed that about a half of EWSR for the GQR strength exists in this bump region according to the results of (α,α') and (e,e') experiments. This

GQR contribution was subtracted from the summed differential cross section calculated from the spectum after subtracting the GDR strength. As a result, about 70 % of E0 sum rule limit is found to exhaust at $E = 12 \sim 24$ MeV. This is inconsistent with the (α, α') result at 240 MeV [5]. In our approach to deduce the GMR cross section, the DWBA calculation with macroscopic form factors may include some ambiguous parameters. We now check the reliabilities of our calculations.

References

[1] A. Tamii *et al.*, *submitted to* Phys. Lett. **B**.
[2] G. R. Satchler, Nucl. Phys. **A195**, 1 (1972).
[3] G. R. Satchler, Nucl. Phys. **A472**, 215 (1987).
[4] G. R. Satchler, Particles and Nuclei **5**, 105 (1973).
[5] D. H. Youngblood *et al.*, Phys. Rev. Lett.**76**,1429 (1996).
[6] M. Fujiwara *et al.*, Nucl. Instr. and Meth. **A422**, 484 (1999).
[7] M. Yosoi *et al.*, *in Porc. 11th Int. Symp. on High Energy Spin Physics*, AIP Conf Proc. No. 343, p157.
[8] S. C. Fultz *et al.*, Phys. Rev.**C10**,608 (1971).

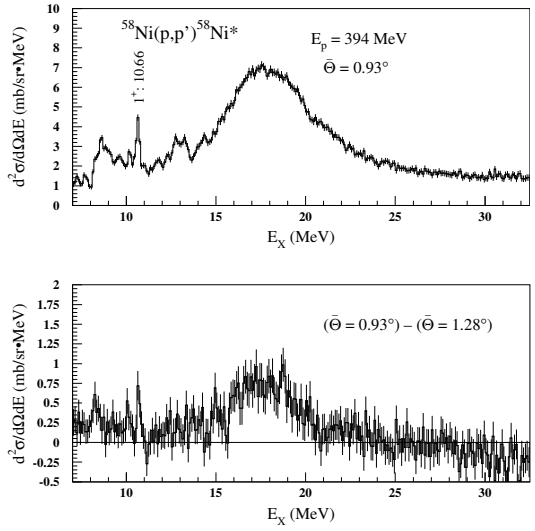

Figure 1: Excitation Spectra of ^{58}Ni

The upper part of Fig.1 shows a ^{58}Ni(p, p') spectrum, and the lower shows a difference of spectra between at forward (0mr $\leq \mid \theta \mid \leq$ 10mr) and at backward (0mr $\leq \mid \theta \mid \leq$ 20mr) angles. The upper part of Fig.2 shows a total spin transfer. The total spin transfer is defined as $\Sigma = (3 - 2D_{SS} - D_{LL})/4)$, where D_{SS} and D_{LL} are polarization transfer observables. The middle part of Fig.2 shows total cross section and spin-flip one (hatched region). The lower shows total cross section and non-spin-flip one (hatched region). Fig.3 shows a subtraction of IVGDR from non-spin-flip cross section.

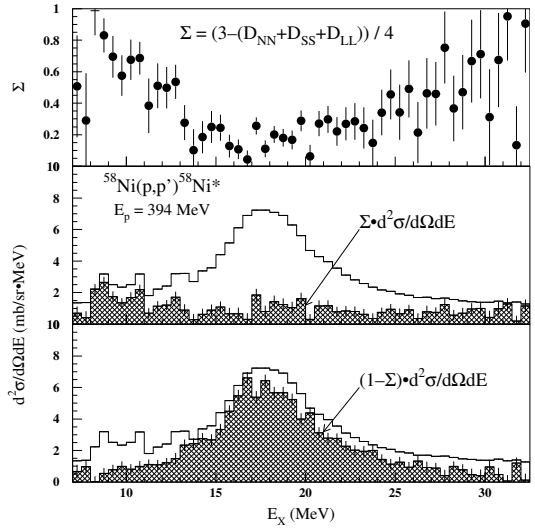

Figure 2: Decomposition of spin modes

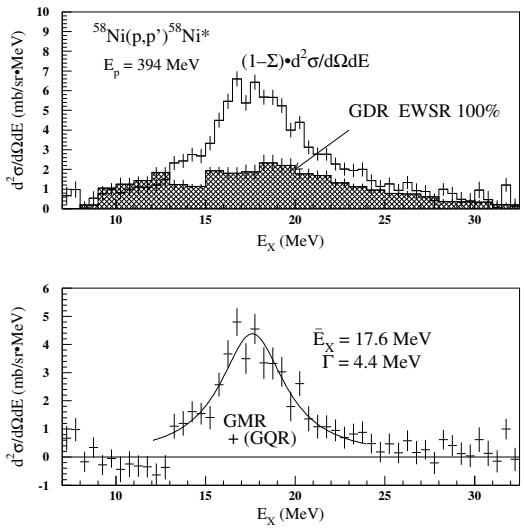

Figure 3: Subtraction of E1 strength