REACTIONS TO CONTINUUM FINAL STATES

A PRAGMATIC APPROACH TO THE CONTINUUM SPECTRUM IN QUASIFREE SCATTERING

G. Ciangaru, C.C. Chang, H.D. Holmgren, A. Nadasen[a], and P.G. Roos
Department of Physics And Astromomy University of Maryland, College Park, Maryland 20742

A.A. Cowley and S. Mills
CSIR, National Accelerator Centre, Stellenbosch, South Africa

P.P. Singh, M.K. Saber, and J.R. Hall
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

During the recent years a considerable attention has been given to the study of the continuum spectrum in the inclusive reactions. In contrast, still very little is known about the continuum spectrum in the exclusive (a,ab) quasifree (QF) reactions. Thus far, it has been customary in the analyses of the knockout reactions to draw continuum background lines in an arbitrary manner. However, a Monte Carlo simulation showed[1] that the contribution from the background to the momentum distrubution can be structured and therefore there is a distinct possibility of misinterpreting it as being part of the quasifree spectrum. The present contribution introduces a method which for the first time allows a quantitative description of the continuum spectrum in the quasifree scattering.

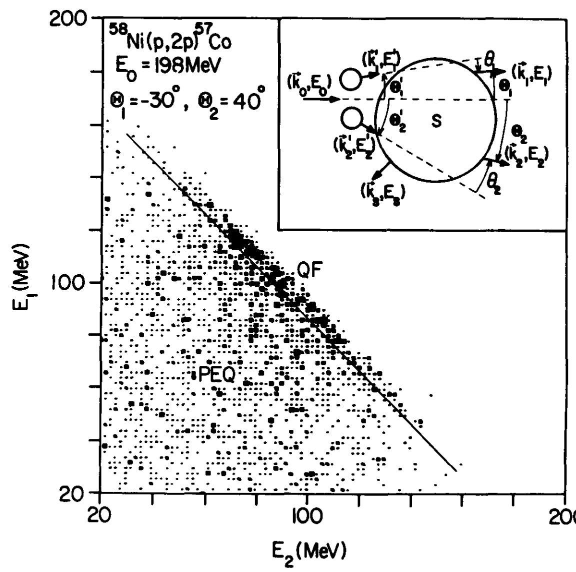

Figure 1. Two-dimensional energy spectrum above the particle evaporation (equilibrium) region.[2] The diagonal line marks approximately the separation between the three-body QF region and the pre-equilibrium (PEQ) continuum region. The inset presents schematically our model of the mechanism of the coincidence continuum.

Our model is based on the following simple physical picture illustrated by the inset in Fig. 1 for a (p,2p) scattering. We postulate that the coincidence continuum spectrum results from the rescattering of the QF particles on the spectator (S) part of the target nucleus. Thus, in the case of the (p,2p) scattering for example, the process of forming the continuum is initiated by a QF collision which excited a two particle-one hole (2p-1h) doorway state having both protons unbound. Upon elevating the Fermi level particles from different ν orbits, there are several such doorway states possible. The doorway states can decay via two routes: into the P_1+P_2+S open channel, thus feeding the QF particle loci, or into more complicated p-h configurations involving a multiple scattering of the two protons on the S nucleus, thus feeding the continuum PEQ spectrum. Notice that, in contrast with Rogers and Saylor,[3] we are concerned here with the particles which, as a result of rescattering, are removed from the QF kinematic loci.

The above ideas can be implemented by extending the formalism of the Feshbach, Kerman, and Koonin[4] statistical theory of the multi-step direct two-body reactions. Thus, we assume that the energy averaged coincidence continuum cross section can be expressed as a convolution of the QF cross section with two chains of subsequent rescattering probabilities, one for each particle. We showed that, in the case of the (p,2p) scattering, it is physically reasonable to further express the rescattering chains in terms of the probability that the two protons from the QF step, with energies E_1 and E_2 at angles Θ_1 and Θ_2 will inelastically scatter to the final angles Θ_1 and Θ_2 with energies E_1 and E_2. We assume that these probabilities are related to the cross section for inelastic (IN) scattering on the S nucleus by the expression

$$\frac{d^2\sigma^{IN}}{d(\Omega_i-\Omega_i')dE_i} \cdot \frac{1}{2\pi\sigma_{TOT}^{IN}(E_i)}$$

where $\sigma_{TOT}^{IN}(E_i)$ is the Θ_i- and E_i-integrated inelastic scattering cross section of the i^{th} proton with incident energy E_i and $\Theta_i = |\Theta_i - \Theta_i|$ is the inelastic scattering angle.

In order to expedite the test of these theoretical ideas we consider here the case when the rescattering of one of the QF particles can be neglected. The (e,e'p) scattering is an example where this should be an excellent approximation. For such situations, the energy averaged coincidence continuum cross section is given by the expression

$$\left\langle \frac{d^4\sigma}{d\Omega_1 dE_1 d\Omega_2 dE_2} (\Theta_1, \langle E_1\rangle, \Theta_2, E_2)\right\rangle$$

$$= \int d\Theta_2' \sin\Theta_2' \sum_\nu \frac{d^3\sigma_\nu^{QF}}{d\Omega_1 dE_1 d\Omega_2'} (\Theta_1, \langle E_1\rangle, \Theta_2', E_2') \, \sigma_{TOT}^{IN}(E_2')^{-1}$$

$$\cdot \frac{d^2\sigma^{IN}}{d(\Omega_2-\Omega_2')dE_2} (E_2'; \Theta_2, E_2),$$

where the QF cross sections, corresponding to the initial instant when particles are not yet lost from the QF kinematic loci, assume distorted waves for the incident particle and particle 1 and plane waves for the particle 2.

For the purpose of this contribution we consider the average yield in a 40 MeV wide slice through the two-dimensional energy (p,2p) spectra centered at $\langle E_1\rangle$=130 MeV, for two angles Θ_1 = -12° and -30° and several positive angles Θ_2. The coincidence data are provided by our recent[2] coplanar measurement of the $^{58}Ni(p,2p)^{57}Co$ reaction using 198 MeV protons from IUCF, and the inelastic scattering cross sections are provided by the available experimental data for E_2=62-MeV protons on ^{54}Fe.[6] Assuming that the rescattering of the p_1 proton with $E_1 > E_0/2$ is mostly at small angles, we will neglect the contribution to the continuum at positive angles Θ_2 coming from the QF protons initially emitted at negative angles Θ_1. Thus, the conditions which we have chosen will allow us to test the above simplified procedure for calculating the continuum spectrum in the (p,2p) scattering. An obvious prerequisite for solving the convolution integral is a correct evaluation of the doorway stage σ_ν^{QF} cross section. Since this is not an observable, we derive the occupancy probabilities of the neutron orbits from the comparison of a DWIA calculation[2] with the data corresponding to the particles detected on the QF loci shown in Fig. 1. The convolution integral assuming that most of the continuum particles come from the $0f_{7/2}$ and $1s_{1/2}$ neutron shell model orbits is compared with the data in Fig. 2. The remarkable agreement which is obtained argues for further pursuing the ideas introduced here.

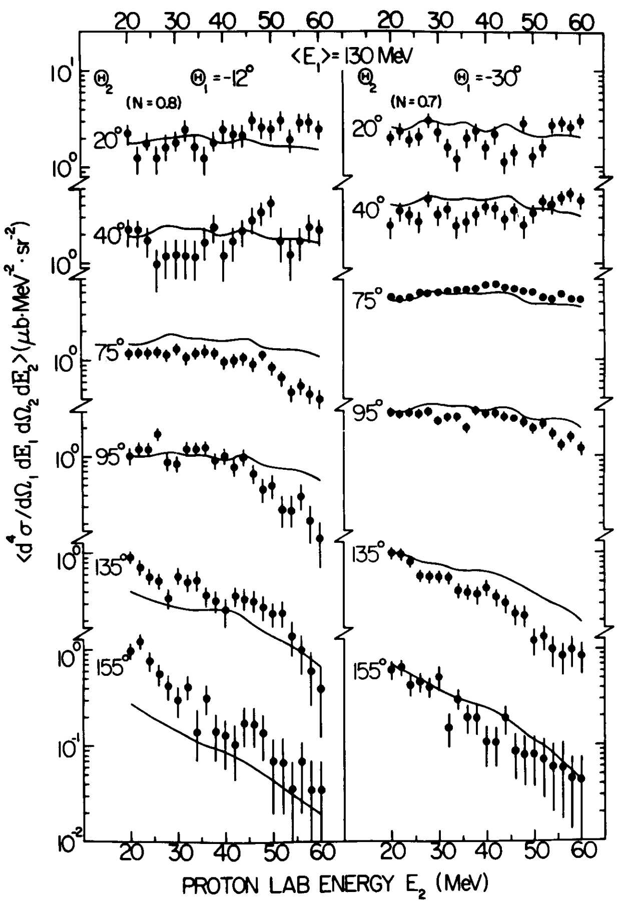

Figure 2. A calculation (full line curves) of the continuum spectrum from the $^{58}Ni(p,2p)^{57}Co$ reaction at E_0=198 MeV. The data correspond to the average yield in a slice through the two-dimensional energy spectra as explained in the text. The agreement in magnitude is reflected by the ratios $N=\sigma_{exp}/\sigma_{theor}$.

(a) Present address: Department of Natural Sciences, University of Michigan, Dearborn, MI 48128

1) K. Nakamura et al., Nucl. Phys. A268, 381 (1976).

2) G. Ciangaru et al., Phys. Rev., to be published.

3) J.G. Rogers and D.P. Saylor, Phys. Rev. C 6, 734 (1972).

4) H. Feshbach, A.K. Kerman, and S. Koonin, Ann. Phys. 125, 429 (1980).

5) G. Ciangaru et al., Phys. Rev. Lett., submitted for publication.

6) F.E. Bertrand and P.W. Peel, ORNL Report No. 4469 (1970).