Electromagnetic Dissociation of Au Targets by Relativistic Pb Projectiles

J.C. Hill^a A. Petridis^a B. Fadem^a F.K. Wohn^a

^a*Iowa State University, Ames, Iowa 50011*

Electromagnetic Dissociation (ED) occurs in collisions of relativistic heavy ions involving impact parameters larger than the nuclear interaction radius. In such collisions strong electromagnetic fields acting at the nucleus can produce, for high charges and ultrarelativistic energies, cross sections much larger than the total nuclear interaction cross section. In ED collisions absorption of a virtual photon generally leads to excitation of a nuclear giant resonance. The NA53 experiment studied ED by bombarding Au targets with 158 GeV/nucleon Pb projectiles from the SPS accelerator. Preliminary values of σ_{ED} for the one- and two-neutron removal processes were determined to be 26.4 ± 4.0 and 4.6 ± 0.7 barns, respectively. Theoretical predictions for σ_{ED} were calculated including the effects of both the E1 and E2 giant resonances. The calculations are extended to energies planned for heavy ion collisions at the RHIC and LHC colliders.

1 Introduction

Relativistic Heavy Ion (RHI) physics emphasizes the study of hadronic interactions at small impact parameters but at the energies planned for the RHIC and LHC colliders most of the reaction cross section for heavy nuclei will result from non-hadronic processes due to electromagnetic interactions. Such a purely electromagnetic process is Electromagnetic Dissociation (ED) which occurs in RHI collisions involving impact parameters larger than the strong interaction radius. Strong electromagnetic fields incident on the nucleus can result in the absorption of a virtual photon by the nucleus which usually results in the excitation of a giant multipole resonance. Deexcitation occurs primarily by means of neutron emission since at giant resonance energies charged particle emission is retarded by the Coulomb barrier. ED was first observed by Heckman and Lindstrom[1] in projectile fragmentation and in fragmentation of Au and Co targets by our group[2]. We report here the initial results from experiment NA53 at CERN. Preliminary values for the one-

Fig. 1. Calculated σ_{ED} for Au targets. The upper and lower curves are for one- and two-neutron removal reactions, respectively, and the solid and dashed curves are for Au and Pb projectiles, respectively.

contributions are for the E1 and E2 (isoscalar and isovector) resonances. The corrections are made using the method of Norbury[8]. The resonance energies and widths used were 10.8 and 2.9 MeV for the isoscalar and 23.0 and 7.0 MeV for the isovector E2 resonances, respectively[9]. A sum rule strength of 95% was used. The prescription for the minimum impact parameter used was that of Benesh et al.[10]. In Figure 1 the measured σ_{ED} for one- and two-neutron removal from Au targets by Pb beams from the SPS measured in this work are compared with the calculations described above. Also shown for comparison are measurements of 1 GeV/nucleon Au projectiles on Au targets by Aumann et al.[11] and 9.9 GeV/nucleon Au projectiles on Au targets by Hill et al.[12]. Although agreement is reasonable the theoretical predictions are systematically too low or high for the one- and two-neutron removal processes, respectively. Llope and Braun-Munzinger[13] suggested that it is possible to

excite a multiphonon giant E1 resonance by absorption of several photons and this effect has been used to partially explain[11] the enhancement of the two-neutron removal process relative to one-neutron removal with 1 GeV/nucleon Au beams on Au targets.

4 Extrapolation to Collider Energies

Due to the large values of σ_{ED} at ultrarelativistic energies ED will be a major determinant of the quality and lifetime of stored beams at the RHIC and LHC heavy ion colliders. The results for both one- and two-neutron removal ED reactions for Au + Au at RHIC are shown on Figure 1. The calculated values are 49 and 7 barns, respectively. The x axis of the figure shows the equivalent energy for a projectile incident on a stationary target. For the beams expected for Pb + Pb collisions at the LHC the corresponding σ_{ED} s are about 92 and 17 barns, respectively.

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and two-neutron removal ED cross sections from Au targets are given. Below we describe the experiment and calculations leading to the measured ED cross sections. The results are compared with calculations using a Weizsacker-Williams virtual-photon spectrum taking into account the effects of both the E1 and E2 giant resonances. The calculations are extrapolated to energies planned for the RHIC and LHC colliders.

2 Experimental Method and Results

Au targets of 0.005 mm thickness were bombarded with 158 GeV/nucleon ^{208}Pb projectiles from the SPS accelerator. Beam intensities were typically 4×10^7 per spill and the total fluence was 3.4×10^{10} projectiles on the target. The beam intensity was determined by counting signals from the NA50 segmented beam hodoscope. The saturation activities for nuclides of interest were measured by counting γ rays for periods of up to several months. The intensities of the 356- and 99-keV γ transitions were measured in order to determine the saturation activities of ^{196}Au and ^{195}Au , respectively. Total cross sections were then calculated for one- and two-neutron removal. A number of corrections described earlier[3] are in the process of being accurately determined, therefore the cross sections reported here are preliminary. In order to separate out the nuclear contribution to the measured cross section the concept of factorization[4] was used. We assume that the yield of a fragment from the target due to nuclear interactions is independent of the beam except through a constant geometric factor that is the same for all fragments. Processes containing significant ED contributions strongly violate factorization. The estimate of the nuclear contribution has a large percentage error but at SPS energies makes only a small contribution to the error of the ED cross section. The preliminary measured results for σ_{tot} , σ_{nuc} and σ_{ED} are given in the Table 1 below.

Table 1

Cross sections for Pb beams on Au targets.

Nuclide	$\sigma_{tot}(b)$	$\sigma_{nuc}(b)$	$\sigma_{ED}(b)$
^{196}Au	26.7 ± 4.0	0.3 ± 0.1	26.4 ± 4.0
^{195}Au	4.7 ± 0.7	0.13 ± 0.04	4.6 ± 0.7

3 Comparison with Theory

The σ_{ED} was calculated by integrating over the product of equivalent photon number N_γ obtained using the method of virtual quanta[5] and the photonuclear cross section σ_γ of Veyssiere et al.[6] multiplied by a factor of 0.93[7]. At ultrarelativistic energies N_γ is the same for different multiplicities but this approximation is not valid at intermediate energies. The only significant