Systematics for one and two neutron transfer in heavy ion reactions

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Introduction

Neutron transfer Reactions play an important role in explaining capture cross section at near fusion barrier energies. The positive Q value of one and two neutron transfer causes a considerable shift in the barrier height, which leads to the enhancement of fusion probability between colliding nuclei [1]. The influence of neutron transfer is in addition to the coupling of inelastic states of the projectile and target.

Van den berg et al. [2] and Rehm et al. [3] introduced a systematic for angle and energy integrated one neutron transfer cross section in heavy ion reactions. Reduced transfer cross sections is used to remove the the influence of the available Q value window and of the neutron binding energy. Reisdorf et al. [4], extended the one neutron transfer systematics including additional data for ^{130}Te and ^{104}Ru targets with Kr beam, which they measured. They could not find a good correlation between σ_{red} and Q_{gg}. In this work, we report one neutron pickup systematics by including 31 projectile target combinations. Also, we report systematics for two neutron pickup transfer for the first time.

Systematics for one neutron pickup reactions

For heavy ion transfer reactions, measured angle and energy integrated cross sections for one neutron pickup were compiled from literature. The energy of the reactions were chosen as 20% above the Bass fusion barrier. In Fig. 1, we show the transfer cross sections for several one neutron pickup reactions as a function of Q_{gg}. To workout a correlation, we

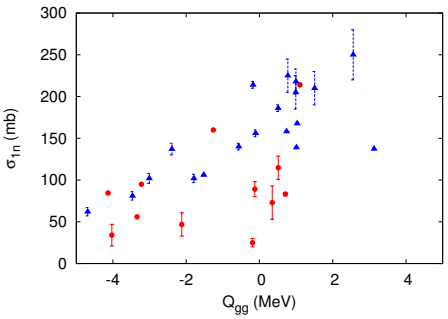

FIG. 1: Angle integrated transfer cross sections for one neutron pickup reactions as a function of Q_{gg}. Triangles and circles correspond to the reactions with $Z_pZ_t \geq 1400$ and $Z_pZ_t < 1400$ respectively.

have separated systems into two groups based on their Z_pZ_t, where Z_p and Z_t are atomic numbers of projecile and target respectively. The transfer cross sections were not corrected for any energy dependence, because for near barrier energies, the dependence of σ_{tr} on E is found to be weak [2]. Van den berg et al. [2] showed that binding energy dependence of angle-integrated quasi-elastic transfer reaction cross sections on the ground-state Q value, has a strong dependence on the product of the binding energies of the transferred neutron in the entrance (B_i) and the exit channels (B_f). They introduced reduced cross section as

$$\sigma_{red}(1n) = \sigma_{exp}(1n) \times (B_i B_f)^{1.1} \qquad (1)$$

Fig. 2 shows the reduced transfer cross sections for several one-neutron pickup reactions as a function of Q_{gg}. The correlation observed between reduced transfer cross section with increasing Q_{gg} can be understood from the Q-matching behaviour [2]. Dotted and dashed

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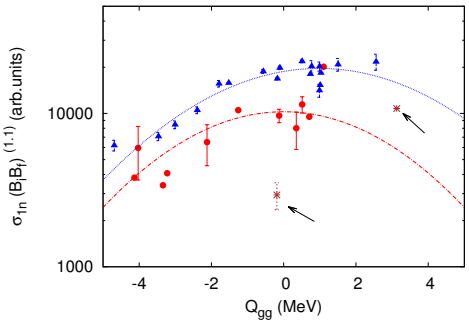

FIG. 2: Reduced cross section plotted as function of Q_{gg}. Triangles and circles correspond to the reactions with $Z_pZ_t \geq 1400$ and $Z_pZ_t < 1400$ respectively.

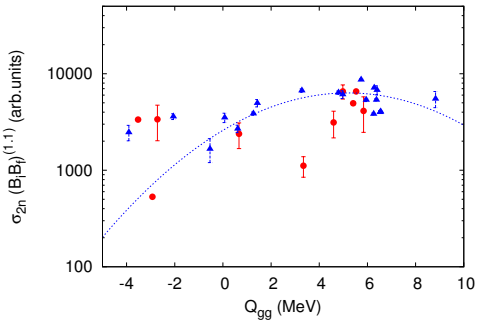

FIG. 3: Reduced two neutron pickup cross section plotted as function of Q_{gg}. Triangles and circles correspond to the reactions with $Z_pZ_t \geq 1400$ and $Z_pZ_t < 1400$ respectively.

lines correspond to a Gaussian function fit with data sets partitioned as $Z_pZ_t \geq 1400$ and $Z_pZ_t < 1400$ respectively. Both data sets are well represented by Gaussian functions with different parameters. Fit for $Z_pZ_t \geq 1400$ set also reproduces the σ_{red} for systems with neutron shell closed target nuclei. Furthermore, the transfer cross section for the reactions involving a target with an odd nucleon number is somewhat lower than expected from the systematics (shown with an arrow in Fig. 2).

Systematics for two neutron pickup reactions

In Fig. 3, we show two neutron pickup cross-section in a reduced form using Eq. (2), where B_i and B_f are binding energy of the transferred second neutron in the entrance and the exit channels respectively.

$$\sigma_{red}(2n) = \sigma_{exp}(2n) \times (B_iB_f)^{1.1} \qquad (2)$$

From Fig. 3, one can observe a good correlation between two neutron transfer cross section and Q_{gg} as observed for one neutron pickup. However, two neutron pickup reactions do not show any Z_pZ_t dependence as seen in the case of one neutron pickup reactions. Also, it is observed that all reactions with negative Q-value except ^{48}Ca+^{124}Sn and ^{64}Ni+^{120}Sn show a deviation from this systematics. As observed in one neutron pickup systematics, the reduced cross section for the reaction ^{32}S+^{93}Nb is lower than expected from the systematics. However, ^{58}Ni+^{149}Sm in which one neutron pickup cross section showed lower than expected from systematics, do not show such a trend in the two neutron pickup.

Conclusion

One neutron pickup reactions for 31 systems were analyzed using systematics introduced by Van den berg et al [2]. Also, a systematics was developed for two neutron pickup reactions. One neutron pickup shows a good correlation between reduced cross section and Q_{gg}, if one separate the systems into two groups based on whether $Z_pZ_t \geq 1400$ or not. For two neutron pickup, such a dependence on Z_pZ_t was not observed. Further investigations are needed for negative Q-value two neutron pickup reactions which showed deviations from the systematics.

References

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