**Nucleon transfer calculations using HIPSE model**

Z. Kohley, D. Lacroix, G. A. Souliotis, A. L. Keksis, B. Stein, D. V. Shetty,
S. Soisson, and S. J. Yennello

The HIPSE (heavy-ion phase-space exploration) model, by Lacroix *et al.*, has been used to examine nucleon transfer during the interaction of the projectile and target [1]. The results of the HIPSE model were compared to experimental data obtained on the FAUST array (Forward Array Using Silicon Technology) for $^{20}F + ^{108}Ag$, $^{20}F + ^{197}Au$, $^{20}Na + ^{197}Au$, and $^{20}Ne + ^{197}Au$ at 32 MeV/u [2]. The apparent mass change of the projectile was calculated for fully reconstructed events, in which the total detected charge was equal to the charge of the beam ($\sum Z_{detected} = Z_{beam}$) [2]. Since neutrons were not detected, the mass change of projectile, ΔN, represents the change in the number of neutrons between the projectile and the reconstructed quasiprojectile, as shown in equation 1:

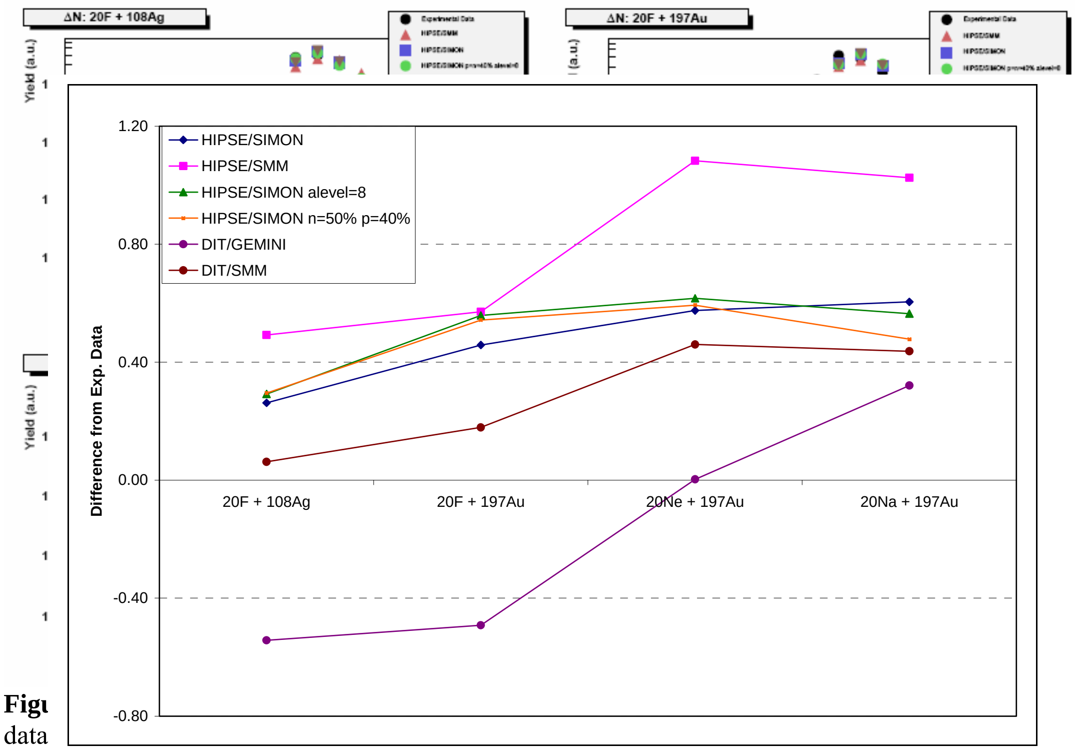
$$\Delta N_{app} = A_{beam} - \sum_{i}^{\text{CP Mult}} A_{fragment,i} \qquad (1)$$

The ΔN is a product of two mechanisms: the transfer of neutrons between the target and projectile and the evaporation of neutrons from the excited QP.

DIT/GEMINI and DIT/SMM was originally used for comparison of ΔN with the experimental data, as shown in Ref. [2]. However, both DIT/GEMINI and DIT/SMM underestimated the transfer of neutrons to the projectile for the less neutron rich systems, $^{20}Na + ^{197}Au$, and $^{20}Ne + ^{197}Au$. These results suggested that DIT was incorrectly accounting for the change in nucleon transfer with respect to the changing N/Z of the system.

HIPSE provides another model in which the interaction, or transfer, stage of the reaction can be examined. HIPSE was used to generate quasiprojectiles for the aforementioned systems. The quasiprojectiles were then de-excited using the SIMON or SMM codes and the resulting fragments were filtered according to the geometrical and energetic acceptances of the FAUST array. The results, shown in Figure 1, demonstrate that the HIPSE calculations are in agreement with the experimental data for the more neutron rich systems. However, for the less neutron rich $^{20}Na$ and $^{20}Ne$ systems the HIPSE results overestimate the neutron loss from the projectile. These results could be attributed to an incorrect amount of transfer between the target and projectile or an overestimate of the loss of neutrons through the pre-equilibrium emission of HIPSE and the free neutron evaporation of SIMON and SMM.

The HIPSE code has a parameterized input for the amount of nucleon transfer between the target and projectile that occurs inside the interaction region. At 32 MeV/u the percent of nucleon transfer was set to 40%. The HIPSE model does not differ in its treatment of neutron or proton transfer. The fact that HIPSE seems to compare better with the more neutron rich systems might eventually be an indiction that the nucleon transfer is isospin dependent. Therefore, the HIPSE model was modified, by Lacroix, in order to allow for the percent transfer of neutrons and protons to be input independently. As shown in Figure 1, when the percent transfer for protons and neutrons are set to 30% and 50%, respectively, only a slight difference is observed. Also shown in Figure 1, is the results of changing the level density parameter, A, in the de-excitation code SIMON. The default value of the level density parameter in SIMON was changed from 10 to 8. The results, again, show no significant changes in the distribution.




Figu
data
with
30%

**Figure 2**. The differences between the simulated and the experimental mean values of the ΔN plots. DIT/SMM and DIT/GEMINI results taken from Ref. [2].

A more quantitative comparison of the different simulation methods used is shown below in Figures 2 and 3. In Figure 2, the differences in the mean values of the experimental data versus the simulation results are shown. It is evident that for the neutron rich systems DIT/SMM is the most accurate, while DIT/GEMINI has the best agreement with the less neutron rich systems. The HIPSE code is clearly overestimating the mean value of the neutron transfer. In Figure 3, the difference between the experimental and simulated distribution widths are plotted. The distribution width is represented by the sigma value from a Gaussian fit of the ΔN plot. It is interesting to note that even though the DIT/SMM results were able to better reproduce the mean values, the HIPSE/SIMON results provide the best overall agreement with the width of the distributions. This suggests that HIPSE is able to better reproduce the amount of reactions in which a large transfer of nucleons is observed, while DIT underestimates the number of large nucleon transfer reactions. The results in Figures 2 and 3 also demonstrate that both the mean values and distribution widths of the ΔN plots are sensitive to the interaction code as well as the de-excitation code. Further examination of the HIPSE code with different variations of the level density parameter, percent transfer of neutrons and protons, and the de-excitation code may provide a better description of the N/Z dependence of the nucleon transfer.

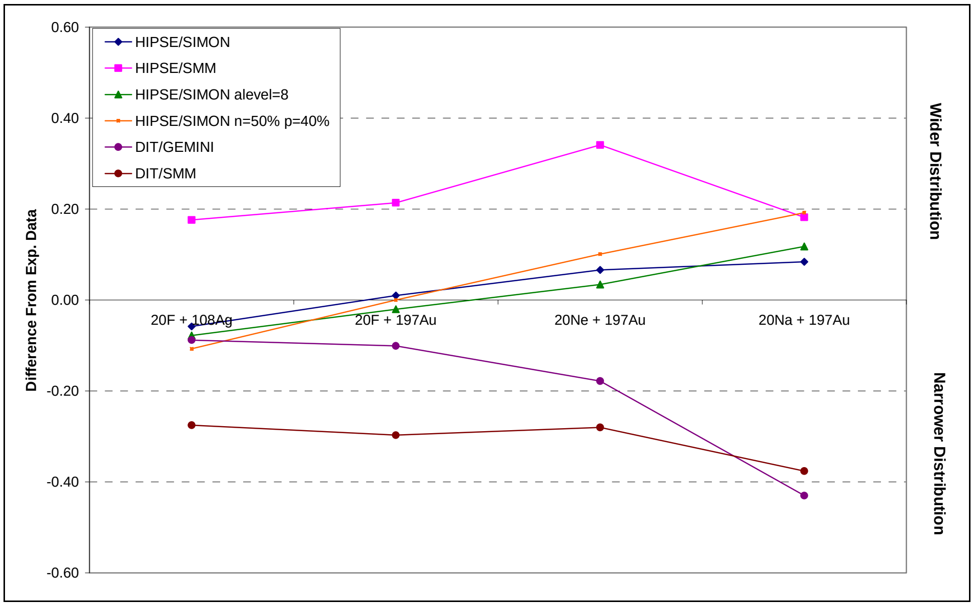



**Figure 3**. The differences between the simulated and the experimental sigma values of the ΔN plots. The sigma value was extracted from a Gaussian fit of the ΔN plot. DIT/SMM and DIT/GEMINI results taken from Ref. 2.

[1] D. Lacroix *et al*., Phys. Rev. C **69**, 054605 (2005).

[2] D. Rowland, Ph.D. Thesis, Texas A & M University, 2000.