N/Z equilibration in deep inelastic collisions

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When target and projectile nuclei have a difference in N/Z, the quasiprojectiles formed in deep inelastic collisions should have a mean N/Z between that of the N/Z of the target and the N/Z of the projectile. This depends on the amount of N/Z equilibration that has occurred. Six reaction systems at two beam energies, 32 and 45 MeV/nucleon, were studied. The systems, in order of increasing difference between target and projectile N/Z (shown in parentheses), were ^{40}Ar + ^{112}Sn (0.018), ^{48}Ca + ^{124}Sn (0.080), ^{48}Ca + ^{112}Sn (0.160), ^{40}Ca + ^{112}Sn (0.240), ^{40}Ar + ^{124}Sn (0.258) and ^{40}Ca + ^{124}Sn (0.480). The projectiles were produced in the advanced electron cyclotron resonance ion source and accelerated by the Texas A&M University Cyclotron Institutes K500 superconducting cyclotron. The fragments from the reactions were measured with FAUST, the Forward Array Using Silicon Technology, which was composed of 68 Si-CsI telescopes that had 90% angular coverage between 2 and 33 degrees [1, 2].

Two techniques were used to determine the quasiprojectile N/Z. The first technique used the isotopically resolved fragments to reconstruct the quasiprojectile N/Z. Reconstruction also provided a route for source determination by requiring that the quasiprojectile charge equaled the projectile charge plus or minus 2. This reconstruction was affected by neutron loss, which made the apparent quasiprojectile N/Z lower than the true value. Reconstruction is described in detail in the appendix of [3]. The second technique, developed in this study, is not neutron dependent. Fragments form in the quasiprojectile source experiencing the N/Z of the source. The fragments therefore retain a memory of the N/Z of the quasiprojectile source.

Using yield ratios, such as the isobaric yield ratios, from a variety of systems that have a range in N/Z of the quasiprojectile source, coupled with a simple equation:

$$\frac{N}{Z}_{Quasiprojectile} = X\frac{N}{Z}_{Target} + Y\frac{N}{Z}_{Projectile}$$

are used to simultaneously fit the fragment yield ratios of all six systems to determine the quasiprojectile N/Z. The X value is the target contribution and the Y value is the projectile contribution. These were found to be 39% and 61%, respectively. The global fitting using all isobaric yield ratios for all systems at 32 MeV/nucleon at 7° is shown in Figure 1. Table I shows the results from both techniques on experimental and theoretical data for all 12 systems. Compared to a fully N/Z equilibrated quasiprojectile, the quasiprojectiles formed in this study are 54% equilibrated [3].

The quasiprojectile N/Z values determined by the yield ratio technique were much larger than those determined by the reconstruction technique. The question arose whether this is caused purely from neutron loss. This question was resolved by using simulations to form (DIT of Tassan-Got) and de-excite (SMM of Botvina) quasiprojectiles. The fragments formed were filtered to the acceptance of FAUST and

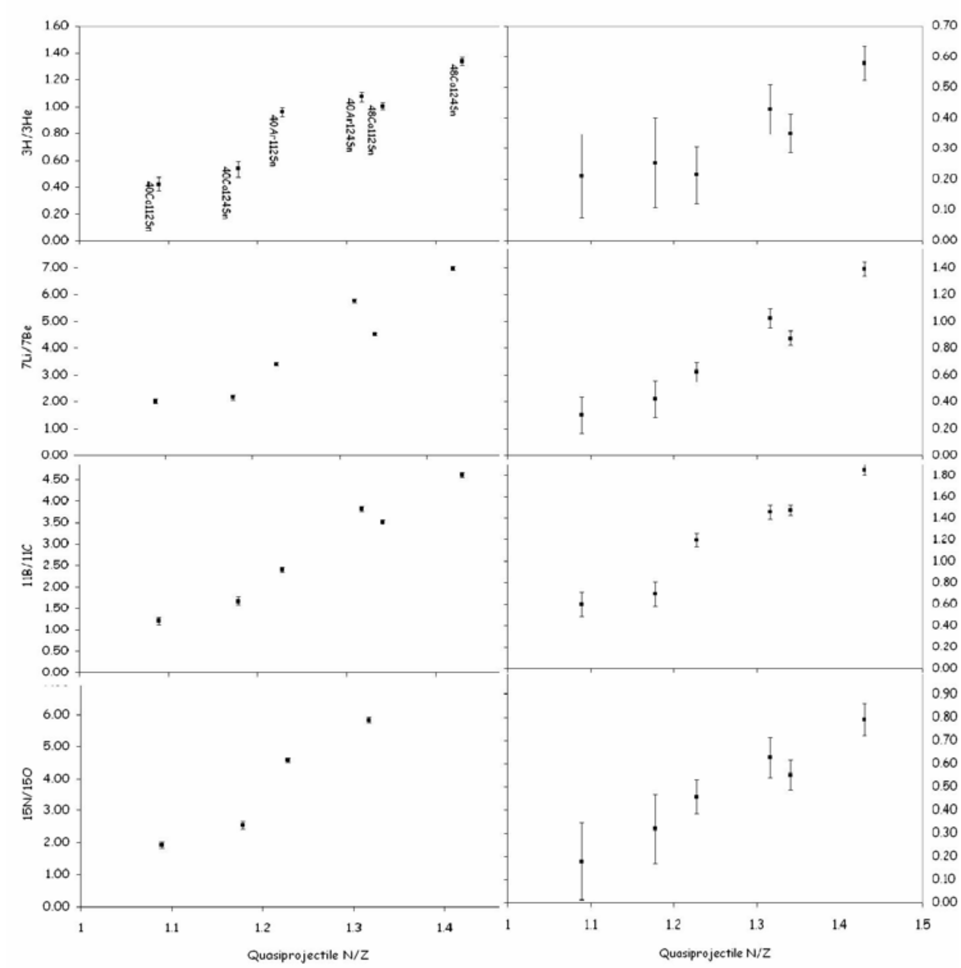

Figure 1. Results of global fitting of the isobaric yield ratios of all six systems at 32 MeV/nucleon at 7°.

then analyzed like experimental fragments, yielding similar results. In the simulations the quasiprojectile N/Z was known and compared to the results that used the yield ratio technique. The comparison showed that the yield ratio technique approximated the quasiprojectile N/Z [3]. Further modification of the equation used in the yield ratio technique, such as taking into account masses of target and projectile, might improve the approximation. Since the quasiprojectile N/Z was known, the neutron loss was calculated and was shown that the more neutron rich systems lose more neutrons (See Table 1). This accounts for the differences between the reconstruction and yield ratio techniques.

Table I. Summary of the results from experiment and DIT/SMM calculations using both techniques. 32 MeV/nucleon systems on top and 45 MeV/nucleon systems on bottom. The calculations have a known N/Z of the quasiprojectile and can be back tracked to study the neutron loss.

System	N/Z Tar.	N/Z Proj.	N/Z Comp. Sys.	N/Z Exp. Recon.	N/Z Exp. Fit.	N/Z Sim. Recon.	N/Z Sim. Fit.	N/Z DIT Back Track	Neutron Loss
^{40}Ar + ^{112}Sn	1.24	1.22	1.24	1.00	1.23	1.03	1.23	1.17	3.36
^{40}Ar + ^{124}Sn	1.48	1.22	1.41	1.02	1.32	1.08	1.34	1.27	4.08
^{40}Ca + ^{112}Sn	1.24	1.00	1.17	0.98	1.09	0.97	1.11	1.04	2.31
^{40}Ca + ^{124}Sn	1.48	1.00	1.34	0.99	1.19	1.00	1.22	1.12	2.86
^{48}Ca + ^{112}Sn	1.24	1.40	1.29	1.03	1.34	1.08	1.33	1.27	5.19
^{48}Ca + ^{124}Sn	1.48	1.40	1.46	1.05	1.43	1.13	1.44	1.39	6.10
^{40}Ar + ^{112}Sn	1.24	1.22	1.24	0.99	1.23	1.02	1.23	1.17	3.73
^{40}Ar + ^{124}Sn	1.48	1.22	1.41	1.01	1.32	1.06	1.30	1.25	4.21
^{40}Ca + ^{112}Sn	1.24	1.00	1.17	0.95	1.09	0.94	1.08	1.03	2.59
^{40}Ca + ^{124}Sn	1.48	1.00	1.34	0.96	1.18	0.98	1.15	1.10	2.97
^{48}Ca + ^{112}Sn	1.24	1.40	1.29	0.91	1.34	1.07	1.35	1.27	5.57
^{48}Ca + ^{124}Sn	1.48	1.40	1.46	0.89	1.43	1.12	1.43	1.38	6.20

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