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IMPLICATIONS OF NEW MEASUREMENTS OF $^{16}O + p \rightarrow {}^{12,13}C$, $^{14,15}N$ FOR THE ABUNDANCES OF C, N ISOTOPES AT THE COSMIC RAY SOURCE

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ABSTRACT

The fragmentation of a 225 MeV/n ^{16}O beam has been investigated at the Bevalac. Preliminary cross sections for mass = 13,14,15 fragments are used to constrain the nuclear excitation functions employed in galactic propagation calculations. Comparison to cosmic ray isotopic data at low energies shows that in the cosmic ray source $^{13}C/C \leq 2\%$ and $^{14}N/O = 3 - 6\%$. No source abundance of ^{15}N is required with the current experimental results.

1. Introduction: The interpretation of cosmic ray measurements in terms of the source abundances and the propagation conditions requires accurate nuclear physics parameters. The current cosmic ray data is, in many cases, better than our ability to interpret it. In particular, the interpretation of the isotopic abundances of carbon and nitrogen, as a function of energy, requires nuclear excitation functions for masses 13, 14 and 15, and we report here preliminary results from an experiment designed to study the fragmentation of ^{16}O at intermediate energy.

2. The Bevalac Experiment: Figure 1 shows the experimental arrangement at the LBL Bevalac. The ^{16}O beam, incident from the right, passed through monitors S1 and S2, focussing and bending magnets, and steering scintillators upstream of the target, located in a vacuum tank. Fragments from interactions in the targets (~ 1 g/cm^2 C and CH$_2$) were measured ~7 meters downstream in the cave with a solid state detector telescope (Scope) which was moveable in order to study the angular distributions of the fragments. The Scope consisted of three x-y

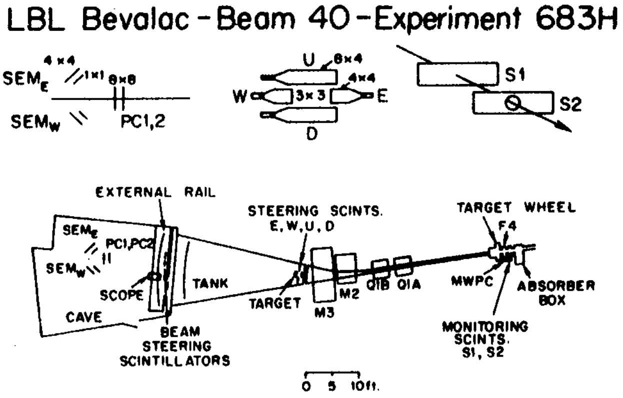

Fig. 1: Experimental Configuration

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*U. of California, Berkeley, Space Science Laboratory planes of position-sensitive detectors and a stack of 30 Li-drifted detectors. The ΔE-E technique was employed to measure the mass of each particle stopping in the scope.

Six angular positions from 0° to 2.75° were studied and the cross sections were obtained by integrating under the normalized angular distributions after correction for background, beam effects, and interactions in the detector stack. Hydrogen target cross sections were obtained by CH_2-C subtraction. The isotopes of B, C, N and O have been analyzed to date, and here we focus on the A= 13, 14, 15 isobars for which the cross sections in hydrogen are:

	This Work	Predicted
A = 13:	24 ± 2 mb	(23.9 mb)
A = 14:	40 ± 4 mb	(50.4 mb)
^{15}N:	27 ± 2 mb	(24.6 mb)
^{15}O:	50 ± 20 mb	(34.2 mb)

compared to the predictions of the semiempirical equations (Silberberg and Tsao, 1973). For ^{14,15}O, significant measurements were obtained only at large angles due to a beam veto circuit used at small angles to reduce the number of ^{16}O nuclei analyzed. The ^{14,15}O measurements were extrapolated to 0° thereby accounting for the large uncertainty. For the astrophysical interpretation, we prefer to rely on the semiempirical values for ^{14,15}O, until additional experimental data can be analyzed.

Figure 2 shows the results of this experiment compared to previous data and to various excitation functions: solid curves -- semiempirical formulae; dashed curves -- scaled from ^{12}C measurements; dot-dash curves -- "limiting" cases (Guzik, 1981; Guzik and Wefel, 1984a). For A = 15, the predicted excitation functions are similar, and the present results are in agreement with semiempirical or scaled predictions. For A = 14, however, the present results are closest to the scaled curve, while for mass 13 the semiempirical curve is indicated. In all cases the

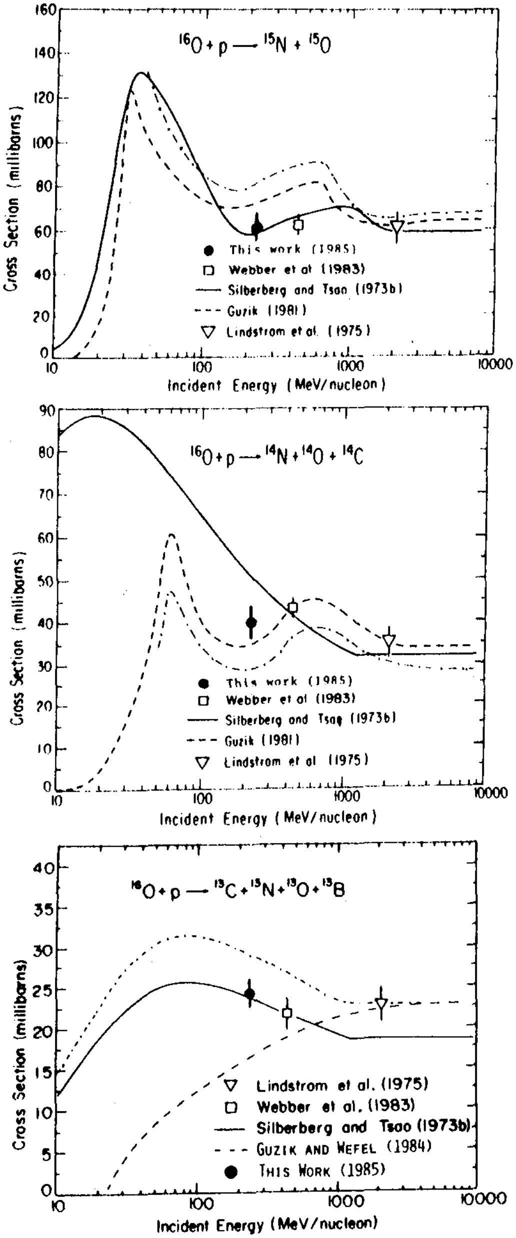

Fig. 2: Excitation Functions for A = 13,14,15 Isobars

measurements do not support the "limiting" curves. It should be noted here that the present results are still preliminary and that measurements at additional energies will be necessary to fully determine the energy dependence of these excitation functions.

3. The Astrophysical Interpretation: Isotopic measurements of nitrogen are presently available at both low and high energy. In the latter case, the results at the cosmic ray source give $(^{14}N/O)_S$ = 5 - 10% with no ^{15}N required (Goret et al., 1983; see also review in Guzik, 1981). At low energy (~ 150 MeV/n), there are several reported isotopic measurements (Guzik, 1981; Wiedenbeck et al., 1979; Mewaldt et al., 1981) whose interpretation depends upon the adopted nuclear excitation functions. Isotopic measurements of $^{13}C/C$ (Mewaldt et al., 1981; Wiedenbeck et al., 1981) provide a $(^{13}C/C)_S$ ratio which can be compared to $^{13}C/C$ measured in different regions of the galaxy (Wannier, 1980).

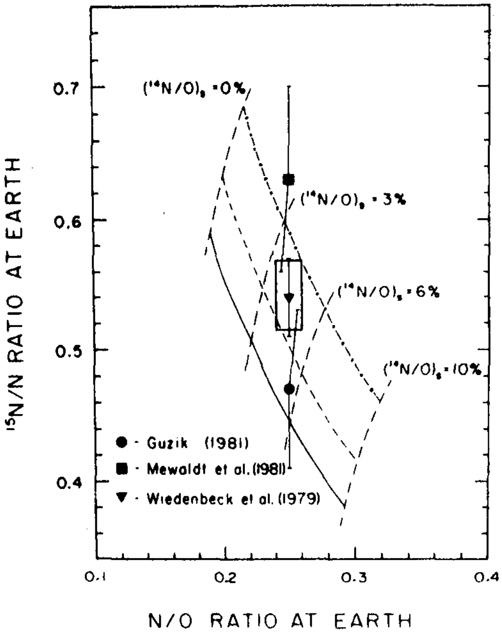

Fig. 3: Results for Nitrogen

The three excitation functions shown on Fig. 2 have been incorporated into cosmic ray propagation calculations using a pathlength distribution with energy dependent parameters, including the depletion of short pathlengths which reproduces the measured B/C and sub-Fe/Fe ratios over the full energy range 0.1 - 50 GeV/n (for details see Garcia-Munoz et al., 1984; Guzik et al., 1985; Guzik and Wefel, 1984a;b). The results are shown on Figures 3 and 4 where the curves correspond to the excitation functions shown on Fig. 2.

The weighted mean of the low energy nitrogen data points (shown individually for comparison) is indicated as the solid box in the center of Fig. 3, and the dashed lines labeled $(^{14}N/O)_S$ give the locus of points for different source abundances (no ^{15}N at the source). For the calculations to reproduce both the elemental and isotopic ratios, at the 1σ level, excitation functions between the scaled and

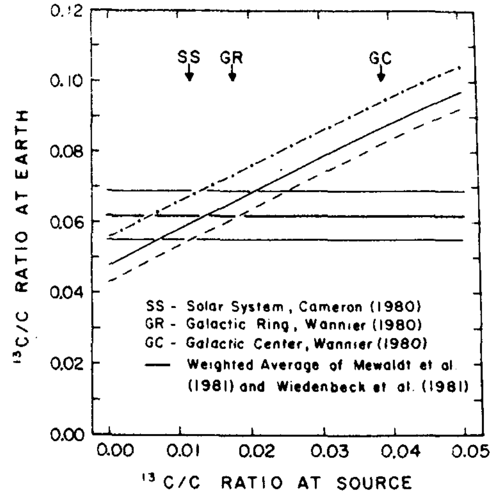

Fig. 4: Results for Carbon

limiting cases are required. Our preliminary cross section measurements, however, indicate a more complicated excitation function falling between the solid and the dashed curves. The results of a propagation calculation using such an excitation function is inconsistent with the 1σ data box on Fig. 3, but in agreement at the 2σ level for $(^{14}N/O)_S = 3 - 6\%$.

Fig. 4 shows the results for $^{13}C/C$. The center horizontal line is the measured ratio with the uncertainty indicated by the lighter horizontal lines. The solid excitation function is favored on Fig. 2 which implies $(^{13}C/C)_S = 1.4 \pm 0.6\%$, in agreement with material found in the solar system but below the ratio observed for matter at the galactic center.

4. Conclusions: Using new cross section data, measured at the Bevalac, for the fragmentation of ^{16}O at intermediate energies, galactic propagation calculations can reproduce the measured $^{13}C/C$ data with a source component $(^{13}C/C)_S = 1.4 \pm 0.6\%$, a value below that observed in the galactic center. The calculated results for nitrogen fall below the average $^{15}N/N$ and N/O ratios but are consistent with the data at the 2σ level for $(^{14}N/O)_S = 3 - 6\%$ and no ^{15}N in the cosmic ray source. Additional nuclear physics measurements are needed to fully specify the excitation functions and to explain, completely, the existing cosmic ray data.

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