LA-UR-97-1745

CONF-970512--11-Add.

Title: ADDENDUM TO: APPLICATIONS OF NUCLEAR DATA IN THE LAHET CODE

Author(s): R. E. Prael
M. B. Chadwick

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Submitted to: For author distribution

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER

Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

DISCLAIMER

**Portions of this document may be illegible
in electronic image products. Images are
produced from the best available original
document.**

ADDENDUM TO: APPLICATIONS OF EVALUATED NUCLEAR DATA IN THE LAHET CODE

R.E. Prael and M.B. Chadwick
Los Alamos National Laboratory, Los Alamos, NM 87545

May 6, 1997

1 Introduction

This document is intended to provide additional information supplementing reference [1]. The discussion describes the details of the implementation of the proton nonelastic cross section parameterization[2] for LAHET usage. It also documents extensions of the method to stable nuclei with $2 \leq Z \leq 5$.

2 Equations of the Parameterization

As noted in reference [1], the equations quoted in [2] are incorrect. However, a corrected set[3] was obtained, implemented, and verified. The actual equations used to produce the proton nonelastic cross sections for isotopes with $Z \geq 6$ are the following.

$E \equiv$ incident proton energy (GeV)

$$r_0 = 1.36$$

$$b_0 = 2.247 - 0.915(1 - A^{-1/3})$$

$$s_0 = 10\pi r_0^2(1 + A^{1/3} - b_0(1 - A^{-1/3}))$$

$$\sigma_0 = s_0 \ln(A - Z) \frac{1 - 0.15e^{-E}}{1 - 0.0007A}$$

$$p_1 = 8(1 - A^{-1} - 0.001A)$$

$$p_2 = 2(1.17 - 2.7A^{-1} - 0.0014A)$$

$$p_3 = 0.8 + 18A^{-1} - 0.002A$$

$$p_4 = 8(0.7 - 0.002A)$$

$$p_5 = 1.37(1 + A^{-1})$$

$$F_1 = \frac{1}{1 + \exp\{-p_1(\log_{10} E + p_2)\}}$$

$$F_2 = 1 + p_3 \left(1 - \frac{1}{1 + \exp\{-p_4(\log_{10} E + p_4)\}} \right)$$

$$\sigma = \sigma_0 F_1 F_2 \text{ (millibarns)}$$

3 Modifications for $2 \leq Z \leq 5$

For $Z \leq 5$, the proton nonelastic cross sections obtained from the above parameterization diverge greatly from the data of reference [4]. To extend the range of the method to lighter isotopes, the the adjustments shown in Table 1 are applied.

Z	A	σ_0	p_1	p_2	p_3	p_4	p_5
5	-	σ_0	p_1	$p_2 + 0.3$	$2p_3$	$0.8p_4$	$p_5 + 0.3$
4	-	σ_0	$0.7p_1$	$p_2 + 0.25$	$7.5p_3$	$0.6p_4$	$p_5 + 0.7$
3	7	$1.1\sigma_0$	$0.7p_1$	$p_2 + 0.3$	$8p_3$	$0.65p_4$	$p_5 + 0.65$
3	6	$1.3\sigma_0$	$0.7p_1$	$p_2 + 0.3$	$12p_3$	$0.8p_4$	$p_5 + 0.5$
2	4	$1.25\sigma_0$	$2.3p_1$	$p_2 + 0.55$	$4p_3$	$0.65p_4$	$p_5 + 0.7$
2	3	σ_0	$2p_1$	$p_2 + 0.9$	$4p_3$	$0.65p_4$	$p_5 + 0.7$

Table 1: Parameter modifications for $2 \leq Z \leq 5$

These adjustments were obtained rather quickly by an entirely empirical, trial-and-error method. The resulting cross sections are shown in Figure 1, along with the data used to obtain the fit. The comparison is good, except for $Z = 2$ which shows need for improvement.

4 Maximum Proton Nonelastic Cross Sections

The tracking algorithm used in LAHET requires the use of some energy independent $\sigma_{max}(A, Z)$ such that

$$\sigma_{max}(A, Z) > \sigma(A, Z, E)$$

for all energies. The following approximation was found that satisfies the need without introducing unnecessary inefficiency into the transport process for protons.

$$\sigma_{max} = s_0 \ln(A - Z)(1 + 2A^{-1} - 0.0026A)$$

where s_0 is calculated as in Section 2. This expression applies for all nuclei with $Z \geq 6$.

References

- [1] R.E. Prael and M.B. Chadwick, "Applications of Evaluated Nuclear Data in the LAHET Code", Los Alamos National Laboratory (May 1997), submitted to International Conference on Nuclear Data for Science and Technology, May 19-24, 1997, Trieste, Italy.
- [2] H.P. Wellisch and D. Axen, Phys. Rev. C **54**, 1329 (1996).
- [3] H.P. Wellisch, private communication to MBC (1996).
- [4] B.C. Barashenkov, Cross Sections of Interactions of Particle and Nuclei with Nuclei, JINR, Dubna, 1993 (Available from the NEA Data Bank at <http://www.nea.fr/html/dbdata/bara.html>).

Figure 1: LAHET parameterization of proton nonelastic cross sections for light isotopes compared with the Barashenkov data compilation[4].