National Institute of Standards and Technology

Nuclear Data Verification and Standardization Program

PROGRESS REPORT

USNDP Meeting
Brookhaven National Laboratory
November 6-7, 2003

Staff (total of about 0.6 FTE):

•Allan Carlson, David Gilliam, and Paul Huffman

•NIST, independent of DOE funds, supplies almost half of the total support for the standards program.

•There is the equivalent of about 1 FTE working on the program.

Nuclear Structure Activities:

•None are supported by DOE funding.

•A modest effort (1 FTE) in structure and decay studies is supported by NIST funds.

Nuclear Reaction Activities:

•Neutron cross section standards:

•Significant improvements have been made in the standard cross section database.

- The emphasis has been on the H(n,n), ^{10}B(n,α), and fission standards.

•The standards are the basis for the neutron reaction cross section libraries.

•In response to requests for improvements in the standards:

- •The CSEWG formed a Task Force
- •The WPEC formed a subgroup
- •The IAEA formed a Coordinated Research Project (CRP)
- •NIST has maintained a leadership role in each of these groups

The International Neutron Cross Section Standards Evaluation

- WPEC and CSEWG
  - Encourage /motivate new measurements where necessary
  - Investigate experimental work to get better information on corrections and uncertainties
  - Mainly interested in the final product, the standards evaluation
- IAEA Coordinated Research Project
  - Refines/improves the evaluation process
  - Seeks to improve the understanding of the uncertainties
  - The focus is on the evaluation process

STANDARDS TO BE EVALUATED

Reaction	Energy Range
H(n,n)	1 keV to 200 MeV
^{3}He(n,p)	thermal to 50 keV
^{6}Li(n,t)	thermal to 1 MeV
^{10}B(n,α)	thermal to 1 MeV
^{10}B(n,$\alpha_1\gamma$)	thermal to 1 MeV
^{197}Au(n,γ)	thermal, 0.2 to 2.5 MeV
^{235}U(n,f)	thermal, 0.15 to 200 MeV
^{238}U(n,f)	threshold to 200 MeV

IAEA CRP
on
Improvement of the Standard Cross Sections for Light Elements

Objectives

• Improve the methodology for determination of the covariance matrix in R-matrix fits**.** Upgrade computer codes using this methodology.

• Study the reasons for uncertainty reduction in R-matrix fits.

• Evaluate cross sections and covariance matrices for neutron induced standard reactions for the light elements,
[H(n,n), ^{3}He(n,p), ^{6}Li(n,t), ^{10}B(n,α) and ^{10}B(n,α$_{1}$γ)]

• Establish the methodology and computer codes for combining the light element with the heavy element evaluations.

CRP Work Now Underway

Members from Austria, Belgium, China, Germany, Japan, the Republic of Korea, Russia, USA

Two RCMs have been held

The second RCM was held at NIST Oct. 13-17, 2003

- Improvements to the experimental data in the standards database
  - In addition to the data sets introduced after the ENDF/B-VI evaluation and before the formation of the CRP, more than 30 data sets have been added to the standards database. Many more are expected before the completion of the evaluation.

- R-matrix evaluations
  - Hale has evaluated the hydrogen scattering cross section below 30 MeV neutron energy using the code EDA. Improvement in the angular distribution was observed compared with recent measurements. Unexpected problems at the 1-2% level appear in the total cross section near 10 MeV neutron energy that require further investigation.

  - The ^{6}Li(n,t) cross section has been evaluated by Hale and Zhenpeng. However they used somewhat different databases and procedures

  - The ^{10}B(n,$\alpha_1\gamma$), and ^{10}B(n,α) cross sections were evaluated by Zhenpeng, but the charged-particle database was not complete

CRP Work Now Underway (cont.)

- Microscopic calculations leading to independent determinations of R-matrix poles for light elements nearing final stages
  - Refined Resonating Group Model used for ^{3}He(n,p)
  - Effective NN potentials used for ^{6}Li(n,t)

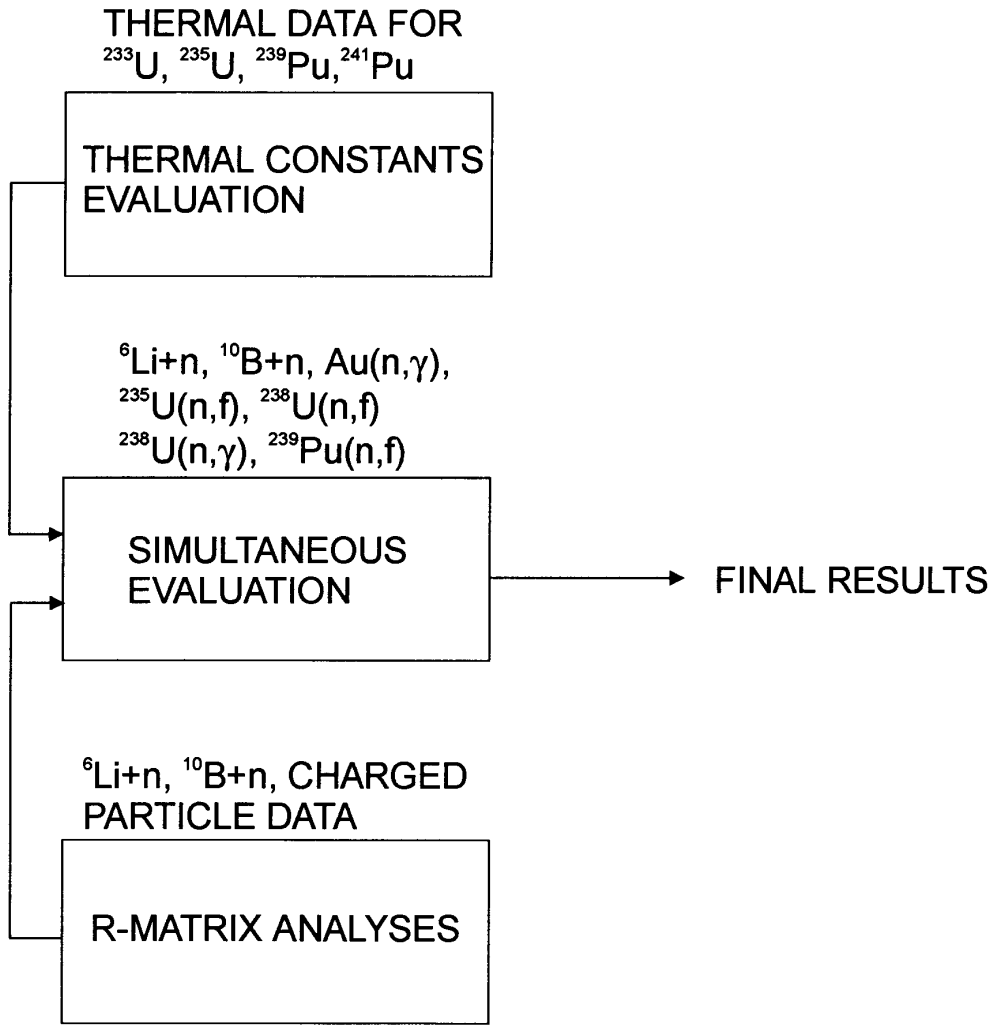
- Generalized least squares evaluations for the ^{6}Li(n,t), ^{10}B(n,α), ^{10}B(n,α$_1$K), Au(n,K), ^{235}U(n,f), and ^{238}U(n,f) standard cross sections.
  - GMA Coding improvement by Pronyaev
  - GMA calculations using 419 sets of data
  - Calculations for Godiva using these ^{235}U(n,f) cross sections
    - MacFarlane NJOY Result is 0.99893 using CSEWG specifications

CRP Work Now Underway (cont.)

- Combining of R-matrix and generalized least squares evaluations
  - R-matrix results for the ^{6}Li(n,t) cross section from the RAC code were used as input to the GMA program to provide a combining of R-matrix and generalized least squares outputs. The R-matrix input was cross section, uncertainty and the correlation matrix.

- Studies of the small uncertainties resulting from evaluations

NEW STANDARDS EVALUATION PROCEDURE



CRP Work Now Underway (cont.)

- Studies of the effect of Peelle's Pertinent Puzzle (PPP) and its effect on the standards evaluation
  - •Results from use of correlated discrepant data
  - •Noticed early in the activities of the CRP
  - •Seen in model independent LS analyses
  - •Maybe not present in EDA R-matrix work
    - •Only normalization and relative uncertainty used
  - •Seen in RAC R-matrix work
    - •Normalization, relative and medium range correlations used
  - • Plans made to test different methods to reduce (or eliminate PPP), e.g. Box-Cox (logarithmic) transformation, weigh by percentage errors, Chiba method, Pronyaev method

- •Methods for handling discrepant data
  - •Poenitz method (down weight data 3 sigma from output results)
  - •Incorporate medium energy range correlation component (yields larger final uncertainty)

CRP Work Now Underway (cont.)

- Comparisons of R-matrix and model independent least squares codes for values of the cross sections and covariances produced
  - Done using 5 ^{6}Li(n,t) data sets, (Fort, Fort & Marquette, Friesenhahn, Lamaze and Poenitz & Meadows)
  - With R-matrix codes, differences are observed near the 250 keV resonance, for relativistic vs non-calculations
  - Model independent codes GMA, GLUCS & SOK agree
  - R-matrix codes give smaller variances than model independent codes
  - Some comparisons of R-matrix and model independent codes done

CRP Work Now Underway (cont.)

- Methods for smoothing evaluated data
  - ^{6}Li(n,t), ^{10}B(n,α) and ^{10}B(n,α$_{1}$γ) data can be fit with R-matrix
  - Models may provide insight on defining curves

- Effects of experimental resolution on evaluated results
  - R-matrix analyses handle resolution effects but model independent codes generally don't
  - Unfolding data used for model independent codes is not appropriate
  - Folding resolution functions into R-matrix and model independent codes is difficult and would result in broadened cross sections for the evaluation
  - The simple approach taken is to not include poor resolution data for the model independent codes

Experimental and other work

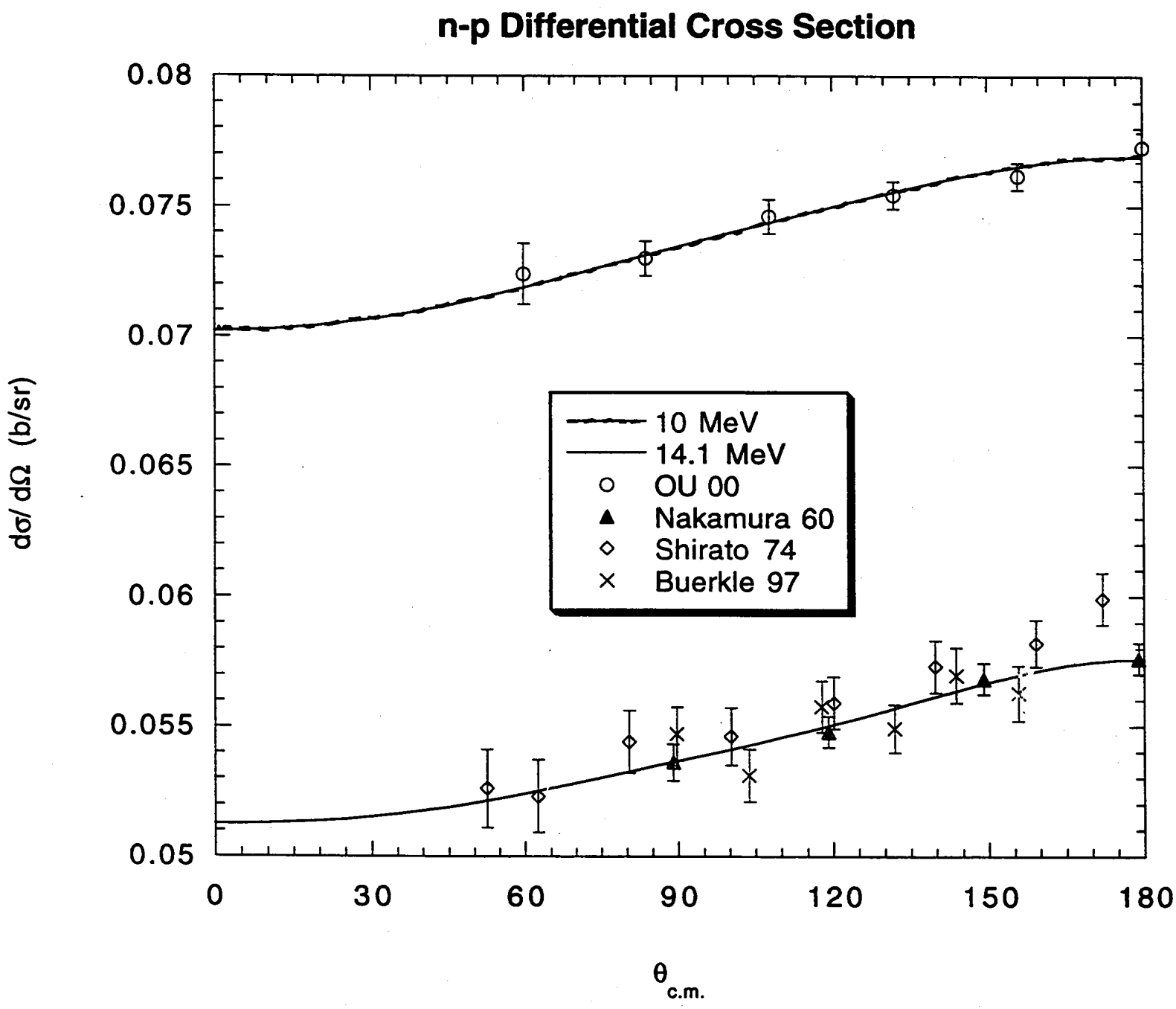
• Hydrogen scattering angular distribution measurements at 15 MeV neutron energy are underway.

(collaboration with Ohio University and LANL)

• The NIST National Repository for Fissionable Isotope Mass Standards continues to acquire and monitor samples.

• Work was done for the 11th International Symposium on Reactor Dosimetry as a member of the Program Committee.

• Improvements continue on a measurement of the ^{6}Li(n,t) cross section standard at ~ 4 meV neutron energy


n-p Differential Cross Section
0.08
0.075
0.07
0.065
0.06
0.055
0.05
dσ/ dΩ (b/sr)
0
30
60
90
120
150
180
θ c.m.
10 MeV
14.1 MeV
OU 00
Nakamura 60
Shirato 74
Buerkle 97

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^{6}Li(n,t) Thermal Data

Author	Cross Section	(b) Comment
Silk et al.	943.8 ± 2.8	Used in V-6 Simult. Eval.
Meadows	936 ± 4	Used in V-6 R-matrix Eval.
Becker et al.	944 ± 19	Used in V-6 Simult. Eval.
Average	941.3 ± 2.3	
ENDF/B-VI	941. ± 1.3	Combination of Simult. Eval and R-matrix Eval.
Simult. Eval. (ENDF/B-VI)	941. ± 1.7	
interim Eval.	937.9 ± 1.6	Does not include the Chowdhuri (NIST) data
ENDF/B-V	935.9 ± 3.7	