Report on USA Experimental Activities

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and

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WPEC 2005 – USA Experimental Activities
Introduction

• The present report is derived primarily from material reported at the annual CSEWG meeting held on 2 – 4 November 2004
• Participation in CSEWG is voluntary, i.e., it not mandated by any USA funding organizations
• Reports are given for the following laboratories:
  - ANL, LANL, NIST, Ohio University and RPI
• Summaries are presented here along with a slide show provided by each listed laboratory
Argonne National Laboratory

- Measurements reported from Argonne were performed at the ATLAS facility in the Physics Division at Argonne National Laboratory
- The research emphasis is on non-energy, basic physics investigations, e.g., astrophysics, heavy-ion fusion, and nuclear structure and decay studies far from the line of stability
- The Argonne nuclear data program, which is primarily dedicated to ENSDF evaluation work, collaborates with researchers at the ATLAS facility and a worldwide network of scientists

WPEC 2005 – USA Experimental Activities
Experimental Activities Report
ANL Nuclear Data Program

Filip G. Kondev
Nuclear Engineering Division

2004 CSEWG Meeting
Brookhaven National Laboratory, November 2-4, 2004

Argonne National Laboratory

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Operated by The University of Chicago
ANL Experimental Activities Overview

- **Measurements with Gammasphere & FMA at ATLAS**
  - Basic low-energy nuclear physics
  - Non-energy applications, e.g. astrophysics, detector efficiency standards and others
  - Nuclear energy applications, e.g. isomers, FP

- **Development of a new generation Ge tracking detectors**
  - both applied and basic physics communities

- **Decay studies of heavy nuclei**
  - both applied and basic physics communities

- **Radioactive HI beams measurements**
  - Intermediate energy Coulomb excitation at MSU – nuclei near $^{48}\text{Ca}$ ($^{50,52,54,56}\text{Ti}$)
Properties of Nuclear K-Isomers in neutron-rich nuclei near A~180 and shell-model isomers near $^{132}$Sn, including spectroscopy of FP – in collaboration with ANU (Canberra), UML and PHY/ANL

Properties of nuclei far from the line of stability - in collaboration with PHY/ANL, UT

- proton-rich nuclei in the rare earth (Re-Ir) and Hg-Pb regions

Spectroscopy of $^{237}$U and $^{239}$U using Unsafe Coulomb excitations – in collaboration with PHY/ANL

Triaxial Superdef and Wobbling mode in $^{171-175}$Hf and $^{170-171}$Ta

Spectroscopy of heavy nuclei – in collaboration with PHY/ANL

- Decay data on $^{253}$Es
- Properties of high-K isomer in $^{254}$No
Measurements with GS & FMA at ATLAS

- Coupling of *Gammasphere & FMA* at ATLAS

- New equipment: 4 Ge CLOVER detectors
Two-quasiparticle Isomer in $^{254}$No?

- A 7⁻ isomer (70 ns) in $^{256}$Fm
- A 1.8 s isomer in $^{250}$Fm.

Challenges

- small production cross sections – $\mu$b or less
- low sensitivity to $\gamma$–ray detection - highly converted transitions
- long lifetimes (ms or more) – more randoms

- $E_\alpha = 8.1$ MeV

A. Ghiorso et al., Phys. Rev. C7 (1973) 2032
Search for electrons following decay in $^{254}\text{No}$

$^{48}\text{Ca} + ^{208}\text{Pb} \rightarrow ^{254}\text{No} + 2n$

$E_{\text{beam}} = 219 \text{ & } 223 \text{ MeV}$

$I_{\text{beam}} \sim 10 \text{ pnA}$

Target : $\sim 0.5 \text{ mg/cm}^2$

Search for electrons following decay in $^{254}$No

Electron-alpha correlation

- No. of $^{254}$No at the DSSD: 1125 (112)
- No. of e - $\alpha$ coincidences: ~ 125

Isomer ratio ~ 11%
Configuration of the 2-qp Isomer

\[ E_{\text{sum}} = \sum_{i=1}^{4} e_i \]

\( e_i = \) energy deposited in the DSSD by the electrons for each transition.

**Predictions**

\[ \pi^2 \ 7/2^-[514] \times 9/2^+[624] \quad \pi^2 \ 7/2^-[514] \times 7/2^+[633] \]

1.2 MeV  
1.4 MeV

**Experiment**

\[ R_{\text{high}} = 0.12(3) \]

\[ R_{\text{high}} = 0.14 \]

**Model, 7^-**

\[ R_{\text{high}} = 0.14 \]

**Model, 8^-**

\[ R_{\text{high}} = 0.32 \]
Los Alamos National Laboratory

- Neutron measurements at LANSCE involve the use of several unique, specialized instruments:
  - GEANIE, FIGARO, DANCE, “n-Z”, & Lead SDS
- Characteristics of the experimental program are:
  - many collaborators (universities & nat’l labs)
  - wide range of elements, isotopes, reactions
  - wide energy range ($E_n = \text{thermal to } > 200 \text{ MeV}$)
  - neutron, photon, and C.P. measurements
  - indirect measurements (e.g., partial Xsect’s)
  - sophisticated data analysis procedures
- Experiment and theory are combined to generate comprehensive isotopic evaluations
Los Alamos National Laboratory

Slide Show

WPEC 2005 – USA Experimental Activities
Robert C. Haight
Los Alamos National Laboratory

Cross Section Evaluation Working Group Meeting
US Nuclear Data Program Meeting
Brookhaven National Laboratory
November 2-5, 2004
Nuclear data measurements at LANSCE are made with several instruments:

- **GEANIE** $(n,x\gamma)$
- **FIGARO** $(n,xn+\gamma)$
- **DANCE** $(n,\gamma)$
- **Other**: $(p,X)$

Other measurements include:

- $N,Z$ $(n,$ charged particle $)$
- Fission
- **LSDS**: Double Frisch-grid fission chamber; also standard fission ion chamber

Logos and affiliations from NASA, Science, and Los Alamos.
Nuclear data experiments at LANSCE use neutrons at three locations: Lujan Center, Target 2 and Target 4.
GEANIE \((n,x_\gamma)\)
Recent & planned GEANIE neutron-induced gamma-ray cross-section measurements at LANSCE/WNR

$\sim 1 \text{ MeV} < E_n < 200 \text{ MeV}$

- $^{191,193}$Ir$(n,n'\gamma)$, $(n,xn\gamma)$, and $(n,pxn\gamma)$ – results ND2004
- $^{197}$Au$(n,n'\gamma)$, $(n,xn\gamma)$, and $(n,pxn\gamma)$ – results APS DNP 10/2004
  - New levels and $\gamma$’s obtained for $^{191,3}$Ir and $^{197}$Au
- $^{100}$Mo$(n,x\gamma)$ – analysis starting
- $^{130}$Te$(n,x\gamma)$ – analysis starting
- $^{70,72,74}$Ge$(n,x\gamma)$ – analysis starting (with INEEL)
- $^{nat}$Cr + $^{nat}$V – relative, for secondary cross section standards
- $^{nat}$Cr + $^{nat}$Fe – same as above – results ND2004
- $^{48}$Ti$(n,x\gamma)$ – dissertation - D. Dashdorj (NCSU/LLNL)
- $^{150}$Sm$(n,2n\gamma)$ – reported (UCRL-TR-205760)
- Planned Samples: $^{124}$Sn, $^{138}$Ba, $^{170}$Er, $^{186}$W, $^{233}$U
New GEANIE data significantly improve the $^{193}\text{Ir}(n,n')^{193m}\text{Ir}$ cross section database.

![Graph showing improvements in the $^{193}\text{Ir}(n,n')^{193m}\text{Ir}$ cross section database with new GEANIE data.](image)
Recent Fe(n,n'γ) $E_γ = 847$ keV relative and absolute measurements at $E_n = 14.5$ MeV agree with JEFF 3.0

- Left – Absolute cross sections using $^{238}$U(n,f) to measure the neutron fluence & cross sections measured relative to $^{52}$Cr(n,n'γ) agree well, but are ~8% larger than ENDF

- Right – Blue curve shows lowering the ENDF $^{56}$Fe Elastic scattering cross section by 8% of the inelastic cross section (preserving the total) gives better agreement with elastic scattering data.
Recent GEANIE (Dashdorj) results for $^{48}$Ti$(n,n' \gamma)$ agree fairly well with the JENDL 3.3 evaluation.

$^{48}$Ti$(n,n' \gamma)$ $E_\gamma = 983$ keV, $2^+ - 0^+$
FIGARO \((n, xn+\gamma)\)
Present and future experiments at FIGARO/WNR: neutron-emission spectra and $\nu$-bar in fission

$1 \text{ MeV} < E_n < 200 \text{ MeV}$

Fission Chamber in beam
- $^{238}\text{U}(n,f)$: $<E_{fn}>$ Ethvignot, Phys. Lett. B
- $^{235,238}\text{U}(n,f)$: $E_{fn}$, $\nu$-bar Ethvigot, paper submitted on $\nu$-bar
- $^{235}\text{U}(n,f)$: $E_{fgamma}$ R. Nelson, in progress
- $^{237}\text{Np}(n,f)$: $E_{fn}$, $\nu$-bar next run cycle

Gamma-ray trigger (HPGe or BaF2)
- $\text{Si}(n,n'\gamma)$ Rochman et al. NIM 523, 102 (2004)
- $^{58,60}\text{Ni}(n,n'\gamma)$ ND2004 contribution
- $^{99}\text{Tc}$, $^{208}\text{Pb}$ In progress
The fission neutron spectrum varies with incident neutron energy.

$^{238}\text{U}(n,f)$ average neutron energy

Agreement with Los Alamos Model is good below 20 MeV.
Neutron emission from neutron reactions is studied as a function of incident neutron energy

$^{28}\text{Si}(n,n')$

We compare our results with GNASH and EMPIRE calculations.

$^{29}\text{Si}$

$^{28}\text{Si} + n$ (target) $\rightarrow ^{29}\text{Si} + n'$

$\rho(J^\pi, E_x) = -8.473$

Trigger

![Graph showing missing mass vs. beam energy and excitation energy vs. beam energy distributions with data points and fitted curves.](Image)
Model-Measurement Comparison for Ni(n,n'γ)
$N,Z = (n, \text{charged particle}) \text{ cross sections}$
We measure proton, deuteron and alpha-particle production cross sections for the Advanced Fuel Cycle Initiative.  

1 MeV < $E_n$ < 100 MeV

- $^{nat}$Fe($n,xp$) + ($n,x\alpha$)  
  Haight, ANS November 2004

- In progress:
  - Cr($n,xp$) + ($n,x\alpha$)
  - Ta($n,xp$) + ($n,x\alpha$)

Goal is to determine, e.g. helium production / dpa for accelerated radiation damage analysis.
New LANSCE data differentiate among evaluations

Iron(n,helium)

Cross Section (b)

Neutron Energy (MeV)
DANCE \((n,\gamma)\)
DANCE Progress 2003 - 2004

Stable Targets:

• $^{197}$Au (well-studied standard)
• $^{139}$La, $^{45}$Sc, $^{55}$Mn, $^{59}$Co, Cu, V, Rb, Sr (Gaps in s-process)
• $^{102}$Pd (rp process)
• $^{62}$Ni (“weak” s-process puzzle)
• $^{151,153}$Eu rad-chem diagnostics

Radioactive Targets

• $^{237}$Np AFCI
• $^{234,235,236,238}$U Known standards and defense programs
• $^{151}$Sm Key s-process branch (largely completed)
$^{237}$Np(n,γ) Preliminary Analysis

Target: 0.44 mg $^{237}$Np in 6.4 mm dia (1.4 mg/cm²)
Existing data above 1 keV discrepant
Test measurements with a fission-tagging detector

- **Study:**
  - Fission-to-capture ratios (“alpha”)
  - Gamma emission following fission
  - “Proof-of-principle” experiment used “thin” $^{235}$U deposit on silicon solar cell
    (T. Ethvigniot, et al.)
- **Future:** Develop thin gas fission chamber

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**Diagram:**

- **Solar Cell Test**
  - $dN/dE_n$ ($/1000 t_0^3$)
  - Fission tag FALSE
  - Fission tag TRUE ($\times 2$)

- **ENDF-B/VI**
  - $^{235}$U$(n,\gamma)$
  - $^{235}$U$(n,\text{fiss})$

T.A. Bredeweg, et al.
DANCE Plans 2004 - 2005

Stable Targets:
• $^{151,153}$Eu rad-chem diagnostic
• $^{72,73,74}$Ge, $^{75}$As, $^{76,77,78,80}$Se, $^{54,56,57,58}$Fe
  (Capture cross sections with better accuracy for s-process studies)

Radioactive Targets
• $^{240,244}$Pu AFCI and defense programs
• $^{147}$Pm s process branch - target irradiated, needs chemistry
• $^{171}$Tm, $^{155}$Eu rad-chem diagnostics, target irradiated, needs chemistry

Development
• Improved hardware handshaking between distributed computers
• Further work on resolution and backgrounds
• Further development of “continuous” data acquisition
• Faster distributed computers, wider-range continuous mode
• Ge detector in concidence for fission studies (??)
• Fission-tagging detector for capture/fission and fission gammas
• Improved neutron monitors – more efficient $^6$LiH, $^{235}$U fission chmbr
Astrophysical neutron-capture reactions studied at DANCE include the following:

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Properties</th>
</tr>
</thead>
</table>
| $^{151}\text{Sm}$ | • radioactive  
• branch s-process point  
• 0.5 mg |
| $^{139}\text{La, Rb, Sr}$ | • closed n-shells  
• integrated neutron flux during s-process  
• s/r ratio in metal poor stars  
• uniqueness of r-process  
• integrated neutron flux during s-process |
| $^{62}\text{Ni}$ | • stable  
• only 25 % of MACS from resonances  
• until recently: 75% had to rely on theory |
| $^{102}\text{Pd}$ | • stable  
• ($n,\gamma$) – ($\gamma,n$) equilibrium during p-process  
• sample only 80% enriched |
Lead Slowing-Down Spectrometer (n,f)
A Lead Slowing-Down Spectrometer is under development, driven by 800 MeV protons from the PSR.

Neutron trajectories following the interaction of 1 proton with the tungsten target in the lead cube.
Lead Slowing-Down Spectrometer: To measure fission cross sections of ultra-small samples

- Effort motivated by interest in measuring the fission cross section of isomers and small samples of actinides

- Calculations show that cross section for $^{235\text{m}}\text{U}$ is significantly different than for ground state

- Experiments are in collaboration with LLNL, RPI and CEA/DAM
First excited state of $^{235}$U is produced in decay of $^{239}$Pu

- $^{235m}$U
  - 26 min half-life
  - 73eV
  - Decays by internal conversion
  - 99% of $^{239}$Pu decays populate $^{235m}$U
  - 5 gm of Pu will produce 10ng of $^{235m}$U

- Fast extraction of $^{235m}$U will be required

- To measure this small cross section, it is necessary to increase the neutron flux by using a lead-slowing down spectrometer (LSDS)
We have characterized the time-energy correlation and measured the resolution in capture resonances. Simulation: \( \langle E_n \rangle = \frac{K}{(t + t_0)^2} \) with resolution, \( \Delta E/E \sim 30\% \).
With the LSDS, we have measured the neutron-induced fission cross section on $^{239}\text{Pu}$ section with sub-µg samples -“High” proton intensity -3h runs -Ultra Small quantity of $^{239}\text{Pu}$ -Good results up to 100 keV
Measuring fission cross sections with double Frisch-grid fission ionization chamber is a new initiative

- Data for the Advanced Fuel Cycle Initiative
- Preliminary data $^{237}$Np (standard fission chamber)
- FY 05: $^{237}$Np, $^{240}$, $^{242}$Pu with Frisch-grid chamber
- People:
  - Tony Hill
  - Fredrik Tovesson
  - F.-J. Hambsch
The double Frisch-grid fission ionization chamber allows good identification of fission. Both fission fragments are detected with Z and A resolution.

Apparatus from F.-J. Hambsch, IRMM
Preliminary measurement of $^{237}$Np fission cross section has been made with parallel-plate ionization chamber.
Radionuclide production by protons at 600 and 800 MeV

- Thesis of Karen Corzine Kelley, Georgia Tech
- Focus on $^{148}$Gd (alpha emitter) produced in LANSCE targets by proton beam on tungsten
- Many other radionuclides also measured
W(\(p,x\))\(^{148}\)Gd production cross section
— Previous predictions and measurements for W
## Cumulative $^{148}$Gd production cross section measurements

<table>
<thead>
<tr>
<th>Target</th>
<th>Energy (MeV)</th>
<th>Foil Setup</th>
<th>cumulative $^{148}$Gd production cross section (mb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Current Measurement</td>
</tr>
<tr>
<td>Ta</td>
<td>600</td>
<td>stacked</td>
<td>15.2±4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>stacked</td>
<td>29.7±7.6</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>single</td>
<td>27.6±1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>single</td>
<td>28.6±7.3</td>
</tr>
<tr>
<td>W</td>
<td>600</td>
<td>stacked</td>
<td>8.31±0.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>stacked</td>
<td>19.5±1.2</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>single</td>
<td>18.0±1.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>single</td>
<td>20.7±5.3</td>
</tr>
<tr>
<td>Au</td>
<td>600</td>
<td>stacked</td>
<td>0.591±0.155</td>
</tr>
<tr>
<td></td>
<td></td>
<td>stacked</td>
<td>3.86±0.98</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>single</td>
<td>3.52±0.22</td>
</tr>
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</table>
$W(p,x)^{148}$Gd production cross section
— Previous predictions and measurements for W

LANSCE-2004
### Other radionuclide production cross section measurements: 800 MeV p + W

<table>
<thead>
<tr>
<th></th>
<th>$t_h$ (d)</th>
<th>current measurement</th>
<th>previous measurements</th>
<th>theoretical</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Titeranko</td>
<td>Henry</td>
<td>CEM2k+GEM2</td>
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<tr>
<td>I-126</td>
<td>13.11</td>
<td>0.599±0.063</td>
<td>11.39±0.46</td>
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<td>0.00±0.00</td>
</tr>
<tr>
<td>Eu-145</td>
<td>5.93</td>
<td>11.1±0.7</td>
<td>18.44±0.82</td>
<td>18.8±1.0</td>
<td>23.9±0.3</td>
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<tr>
<td>Eu-147</td>
<td>23.96</td>
<td>19.5±0.6</td>
<td>21.72±0.98</td>
<td></td>
<td>29.1±0.3</td>
</tr>
<tr>
<td>Gd-149</td>
<td>9.38</td>
<td>19.8±0.5</td>
<td>25.34±1.23</td>
<td></td>
<td>24.7±0.3</td>
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<tr>
<td>Gd-153</td>
<td>241.60</td>
<td>22.9±0.9</td>
<td>59.89±2.25</td>
<td>57.1±1.7</td>
<td>38.4±0.4</td>
</tr>
<tr>
<td>Yb-169</td>
<td>32.01</td>
<td>53.2±1.5</td>
<td>59.70±2.12</td>
<td></td>
<td>37.3±0.4</td>
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<tr>
<td>Lu-171</td>
<td>8.24</td>
<td>60.0±3.7</td>
<td>61.66±3.09</td>
<td>55.3±2.4</td>
<td>37.9±0.4</td>
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<tr>
<td>Lu-173</td>
<td>499.69</td>
<td>52.3±1.4</td>
<td>56.04±2.13</td>
<td>53.2±2.1</td>
<td>35.2±0.4</td>
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<tr>
<td>Hf-172</td>
<td>682.40</td>
<td>41.1±2.9</td>
<td>48.91±2.80</td>
<td>43.9±2.2</td>
<td>34.5±0.4</td>
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<tr>
<td>Hf-175</td>
<td>70.00</td>
<td>49.3±1.4</td>
<td>56.04±2.13</td>
<td>53.2±2.1</td>
<td>35.2±0.4</td>
</tr>
<tr>
<td>Hf-181</td>
<td>42.40</td>
<td>1.11±0.04</td>
<td>1.4±0.1</td>
<td>0.434±0.044</td>
<td>2.18±0.08</td>
</tr>
<tr>
<td>Ta-182</td>
<td>115.00</td>
<td>12.2±0.2</td>
<td>16.95±0.85</td>
<td>13.0±0.4</td>
<td>8.07±0.19</td>
</tr>
<tr>
<td>Re-184</td>
<td>37.96</td>
<td>1.34±0.05</td>
<td>1.5±0.1</td>
<td>2.07±0.10</td>
<td>1.50±0.06</td>
</tr>
</tbody>
</table>
We address the needs of LANSCE sponsors

• National Nuclear Security Administration
  – Program in radchem cross section measurements
    » Neutron capture cross sections on radioactive targets (DANCE)
    » Cross section measurements on high-order (n,2n), (n,xn) reactions (GEANIE)
  – Program in neutron-induced fission measurements
    » Fission product distributions (GEANIE)
    » Energy output in fission: neutron and γ-ray spectra (FIGARO)
    » Nuclear properties of fission products and isomers (GEANIE and FIGARO)

• Office of Nuclear Energy
  – Measurements in support of the AFCI program include:
    » Capture and fission cross section on actinides
    » Gas production: (n,p), (n,α) reactions in structural materials

• Office of Science
  – Support of SNS in understanding pulsed radiation effects on liquid mercury targets
  – Fundamental physics experiments and nuclear data

• National Resource
  – Nuclear science User Facility for defense, basic and applied research
  – Industrial testing of semiconductor devices in neutron beams
  – University research in nuclear science
The LANSCE program in nuclear data involves many laboratories

- GEANIE – LANL, LLNL, Bruyères-le-Châtel, NC State
- FIGARO – LANL, Bruyères-le-Châtel
- N,Z – LANL, Ohio U
- DANCE – LANL, LLNL, ORNL, Colorado School of Mines, FZK Karlsruhe
- LSDS – LANL, LLNL, Bruyères-le-Châtel, RPI
- Proton – LANL, Georgia Tech
- Others – MIT, Kentucky, Kyushu, Harvard,…
National Institute for Standards and Technology

Slide Show
National Institute for Standards and Technology

- The emphasis of the NIST program is in the areas of neutron cross section standards and high precision, low-energy neutron measurements
- Experiments are performed at the NIST reactor facility and through collaborations at several other facilities, e.g., those at Ohio University and LANL
- NIST has been heavily involved in recent years in promoting and organizing measurements at several laboratories worldwide in support of the international neutron standards evaluation project

WPEC 2005 – USA Experimental Activities
Recent Improvements to the Database for the Evaluation of the Neutron Cross Section Standards from Recent Work at NIST

Allan D. Carlson
Ionizing Radiation Division
National Institute of Standards & Technology

Presented at
The CSEWG meeting
Brookhaven National Laboratory
November 2, 2004
H(n,n)H Recent Work

• NIST Coherent Scattering Length data
  • $b_{np} = -3.7384 \pm 0.0020$ fm
• Ohio University-NIST-LANL
  15 MeV angular distribution experiment
\(^{3}\text{He}(n,p)\) Recent data

- NIST-Indiana University-LANL total cross section data
- NIST Coherent Scattering Length data
  - \(b = 5.872 \pm 0.0072 \text{ fm}\)
$^6$Li(n,t) Recent data

- NIST thermal measurement
- Agrees excellently with CRP results
  - 937.86  GMA database
  - 938.02  EDA
  - 938.38  RAC
  - 940.98  ENDF/B-VI
$^{10}\text{B}(n,\alpha)^7\text{Li}$ Recent data

- NIST Wasson total cross section
Comparison of B-10 total cross section measurements of Wasson et al. at two different flight paths.
$^{235}\text{U}(n,f)$ Recent data

- Use of Arif Coherent Scattering data to improve K1 value ($K1 = \nu \sigma_f - \sigma_a$)
Ohio University

• The experimental work is performed at the Ohio University Accelerator Laboratory in Athens, OH.
• The nuclear data program focuses on measurements of the n-p cross section, methods for calibrating neutron detectors and spherical shell transmission measurements for iron.
• This report summarizes work that has been done and work that has been proposed.
Nuclear Data Measurements at the Ohio University Accelerator Laboratory

Steven M. Grimes
Ohio University
Ohio University Accelerator Lab

- 4.5 MV tandem accelerator
  - Research program focused on neutron-induced and neutron producing reactions.
  - Recent projects completed are in the areas of n-p scattering, neutron source characterization, and spherical shell transmission measurements.

- n-p Scattering
  (Collaboration with NIST and LANL)
  - Precision measurement completed of the angular distribution at 10 MeV.
  - 0 to 60 degrees in lab.
  - <1% errors except at 60 degrees (1.5%).
  - Published in Phys. Rev. C.
  - New results in agreement with Arndt and Nijmegen predictions.
  - New angular distribution measurement now underway at 15 MeV.
  - Additional work is being considered by detecting the neutrons so that a larger range of angles can be measured.
• Neutron Sources
  • Used for rapid and accurate calibration of neutron detectors.
  • Al(d,n) stopping target measured at 20 degrees for \( E_d = 7.44 \) MeV.
    • Data obtained relative to 235U(n,f) cross section.
    • Most accurate from 1 to 6 MeV but useful from 200 keV to 14 MeV.
    • Improvements are being considered.
  • \(^9\)Be(p,n) for \( E_p \) from 3 to 5 MeV using stopping target also measured.
    • Larger cross section than Al(d,n).
    • But more structure in spectra than Al(d,n) and high energy cutoff is lower.
  • \(^{11}\)B(d,n) measured at \( E_d = 5 \) and 7.5 MeV.
    • Larger cross section than Al(d,n) and higher end point energy.
    • But more structure in spectra than Al(d,n).
  • Future work will include at least one \((^3\text{He},n)\) spectrum to obtain an endpoint in neutron energy above 20 MeV.
• Spherical Shell Transmission Measurements
  (Collaboration with NIST and the University of Florida)

  • Spherical-shell transmission measurements have been made for natural iron spheres. The data were obtained using TOF with a 5-meter flight path. The measurements were obtained for two different spherical shells, two different source reactions $^{15}\text{N}(p,n)$ with $E_p=5.1 \text{ MeV}$; $D(d,n)$ with $E_d=3, 5$ and 7 MeV] and laboratory angles of $0^\circ, 45^\circ, 90^\circ, 120^\circ$ and $135^\circ$. The source spectra (without a spherical shell) were measured at laboratory angles of $0^\circ, 15^\circ, 45^\circ, 60^\circ, 90^\circ, 100^\circ, 120^\circ$ and $135^\circ$.

  • Calculations have been made of neutron transport through the shells. Comparison of the measured data with these results calculated with evaluated cross sections can provide information on energy regions where additional work should be done on these cross sections.
The "sphere-on" spectra obtained with the large (8-cm-thick) sphere and for the 15N(p,n) reaction with 5.1 MeV protons incident on the gas. All of the measured angles are shown.
The "sphere-on" spectra obtained with the large (8-cm-thick) sphere and for the D(d,n) reaction with 3 MeV deuterons incident on the gas.
Comparison of 3MeV D(d,n) Monte Carlo calculations and experimental data for the 0 degree angle. (8 cm thickness sphere).
3 MeV D(d,n) 8 cm thickness sphere (zero degrees)
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• Experimental work at RPI is performed at the Gaertner Linac Laboratory in Troy, NY
• The program focuses on neutron transmission and capture measurements as well as on experiments performed with the RPI Lead SDS
• A new gridded ionization chamber for use in fission measurements is being constructed
• The present report highlights experimental measurements, data analysis, and instrumentation development work carried out at RPI during 2004
Rensselaer Polytechnic Institute

Slide Show

WPEC 2005 – USA Experimental Activities
Cross Section Measurements and Analysis at Rensselaer

Report at CSEWG 2004

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and

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Measurements Completed this year

Rh

• Used 7 metallic samples, thickness range of 1-100 mils.
• Thermal (0.005-20 eV) and epithermal (5-1000 eV) transmission and capture measurements.

Mo

• Performed experiment in the epithermal range with thick metallic samples (100-250 mils).

$^{164}\text{Dy}$

• 7 liquid ($\text{D}_2\text{O}$) samples were prepared with 98% enriched $^{164}\text{Dy}$. Two metallic samles were also used.
• Epithermal transmission and capture measurements were completed.

Lockheed Martin
Measurements Completed this year (Continued)

• Developed a method for using the RPI multiplicity detector for alpha measurements.
  • First test measurements using $^{235}\text{U}$ were completed.
  • The results will be used to design future experiments.
Planned Measurements

• Transmission and capture on Re, $^{153}$Eu and F.

$^{236}$U

• Transmission thermal and epithermal measurements were done with a sample of 89.2% enrichment.

• 0.5 g enriched 99.8% $^{236}$U sample has been located for capture measurements.

• Alpha for $^{235}$U

• Thermal to ~50 eV.
Data Analysis

Nb
• Analysis completed

Gd
• Analysis in final stage

Rh
• Transmission analysis started using SAMMY

Cd
• Data analysis started

Lockheed Martin
New Capabilities

• Transmission measurements at the 100 m flight path station with a large neutron detector (~104 cm x 70 cm).

  • Allows high energy and high resolution transmission and spectra measurements in the energy range 0.5-10 MeV.

  • In development, first measurements are planned.

  • Detector and electronics have been obtained and are now being tested.

• LINAC Injector Upgrade

  • Provide shorter pulses (<10 ns), higher current (several amperes peak current), better emittance and commercially available spare parts.

  • Installation underway - completion expected in the middle of 2005.

Lockheed Martin
New capabilities - Fission

- Measurements of the kinematics of fission fragments of small samples.
  - Use
    - A double gridded fission chamber
    - Lead slowing down spectrometer
  - The detector was designed and constructed and is now being tested
  - A $^{252}\text{Cf}$ sample (on a very thin backing) for tests is now in preparation at ORNL
  - First runs with a $^{235}\text{U}$ sample are expected in 2005

Lockheed Martin
--- The End ---