The Progress on LANSCE Experimental Activity

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Outline

• Neutron-capture study: DANCE Status and Upgrade of NUANCE
  • $^{236}$U(n,γ) results
  • $^{63}$Cu(n,γ) results
  • $^{239}$Pu(n,γ) results

• Photon Strength Function Study for unstable nuclei: Apollo at ANL
  • $^{96}$Zr(d,pγ) updates
  • $^{57}$Fe(d,pγ) updates

• NZ study: LENZ status
  • $^{16}$O(n,α) updates
  • $^{95}$Mo(n,p) $^{52}$Cr(n,α) reactions
  • $^{60,61,62}$Ni(n,p) reaction
NEUANCE – NEUtron detector Array at daNCE

- High detection efficiency and energy sensitivity
- Fast time response
- Quality of Pulse Shape Discrimination
- Compact size that can fit inside the DANCE calorimeter
Pulse Shape Discrimination and Time of Flight measurement using Stilbene crystal

- Threshold is about 40 keVee, with a dynamic range of up to 2 MeVee
- Total efficiency of detecting neutrons is estimated to be 28-40 % per $^{252}$Cf fission
Dance : $^{236}\text{U}(n,\gamma)$ result led by B. Baramsai

$^{236}\text{U}(n,\gamma)$ targets with each mass of 64 $\mu$g and 30 mg, so $^{235}\text{U}$ cross section was used as a reference.

Systematic uncertainties (1-100 keV)

<table>
<thead>
<tr>
<th>Uncertainty Source</th>
<th>$dX / X$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical</td>
<td>&lt;0.1-3 %</td>
</tr>
<tr>
<td>Background Subtraction</td>
<td>~1.7 %</td>
</tr>
<tr>
<td>Experimental Corrections</td>
<td>~2.2 %</td>
</tr>
<tr>
<td>Width fluctuation</td>
<td>1.7%</td>
</tr>
<tr>
<td>Reference CS ($^{235}\text{U}$)</td>
<td>1%</td>
</tr>
<tr>
<td>Total</td>
<td>4-8%</td>
</tr>
</tbody>
</table>
Copper isotopes are important for weak s-process nucleosynthesis, in particular neutron capture on $^{63}\text{Cu}$ produces the unstable $^{64}\text{Cu}$. $\beta^+$ decayed $^{64}\text{Ni}$ shields $^{64}\text{Zn}$ from the contributions of the r-process.
The $^{63}\text{Cu}(n,\gamma)$ cross section measured via 25 keV activation and time-of-flight

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Dance: $^{239}$Pu(n,γ) cross section led by S. Mosby

- DANCE Uncertainty is dominated by systematic uncertainty
- Thick target measurement with a beam time less than 14 days
- No fission tagging, so only $\gamma$-ray multiplicity = 7&8 was used for identifying fissions

*Thin $^{239}$Pu target DANCE measurement by S. Mosby et al. PRC 89, 034610 (2014)*
How to improve $^{239}$Pu(n,γ) measurement

• Use a less contaminated $^{239}$Pu target
• Optimized closed packed geometry at DANCE will improve photo-peak efficiency by more than 10%
• Optimize moderator design inside DANCE ball will increase NEUANCE efficiency to play as more efficient and active fission veto detector
• Overall systematic uncertainty will be improved by a factor of 2-4

• Background contribution of DANCE $^{239}$Pu measurement at Lujan is sensitive to timing resolution
• Fission induced BG is the largest, so subtracting BG vs. vetoing BG out will impact final signal to noise ratio tremendously
This is a benchmark study of understanding the photon strength functions on rare-isotopes by comparing to a direct neutron capture measurements.
• 2d plot of the gamma-ray cascade vs. the excitation energy in $^{58}\text{Fe}$
• Complementary to DANCE measurements, since this allows to measure $\gamma$-ray decays below the neutron separation energy of 10.04 MeV
$^{16}$O(n,α) measurement updates

Detected particle energy vs. neutron Time-of-Flight

Reaction Q-value vs. detected LAB angles

Kinematic curve of $^{16}$O(n,α) reaction

Cross section is being deduced from the experimental yields by applying corrections and normalizations for the amount $^{16}$O and a beam flux
$^{16}$O(n,α) data: Forward Propagation Analysis

With well characterized experimental response functions and systematically varying input cross sections, we plan to analyze data “inclusively” by fitting yields in Monte Carlo framework.

**Measured detector resolution & efficiency**

“Measured” target profile

Estimated beam resolution

Calculated R-matrix cross section

Predicted from LANL R-matrix analysis by J. Hale
Forward Propagation Analysis requires to validate MC simul. in order to achieve the reduced systematic unc.

Hit patterns in DSSD for Th-229 is compared between LENZ GEANT simulation and measurement.

LENZ data
LENZ : Scheduled experiment in 2016

• Reaction model study including level density, strength functions, etc. through (n,p) and (n,α) measurements at LANSCE, in particular to up to 20 MeV neutron energy

• Plots show the Hauser-Feshbach calculations on Mo isotopes (LEFT) and the lack of experimental data on $^{52}\text{Cr}(n,\alpha)$ in comparison to evaluations (RIGHT)
Development of direct \((n,z)\) measurement on radioactive nuclei produced at Isotope Production Facility (IPF)

IPF at LANL can provide a radioactive target to be used at LANSCE for measuring \((n,z)\) reactions directly. For the interest of heavy ion production via \(\nu p\) process in explosive environment, we are developing a \(^{56}\text{Ni}\) target to study \((n,p)\) cross section

Benchmark measurements on stable \(^{60,61,62}\text{Ni}(n,p)\) reactions are scheduled in Dec. to guide the radioactive production and study beam induced backgrounds
Summary

- DANCE and LENZ at LANSCE and Hellos+Apollo at ANL can provide high quality data for neutron capture and neutron-induced charged particle reactions, in particular expanding our reactions studies to radioactive nuclei directly.

Collaborators:
- C-NR: B. Baramsai, T.A. Bredeweg, M. Jandel (left LANL), G. Rusev, C.L. Walker