Characterization of Giant Dipole Resonance excitation mode using photon probes at ELI-NP

Mateusz Krzysiek

Nuclear Photonics
June 24 - 28, 2018, Brasov, Romania
**Gamma Above Neutron Threshold - ELIGANT**

Dipole excitations

**IVGDR**

**PDR**

**Tamii et al., PRL-107(2011)062502**

\[ E_{p} = 295 \text{ MeV} \]

\[ \theta_{\text{lab}} = 0^\circ - 2.5^\circ \]
PDR and GDR

ELIGANT-GN

Gamma detection:
\[ \text{LaBr}_3(\text{Ce}) + \text{CeBr}_3 \]

Neutron detection:
\[ ^6\text{Li-glass} + \text{NE213} \text{ (liquid) scintillators} \]

p-process nucleosynthesis and
New Compilation of \((\gamma, xn)\) cross sections

ELIGANT-TN

\(^3\text{He counters}\) embed in polyethylene
Flat-efficiency 4π neutron detector (ELIGANT – TNF)

**3He counters:** conversion of neutrons into charged particles \( ^3\text{He}(n,p)^3\text{H} \)

- Dimensions of detector: 2.5 cm x 49.5 cm
- Gas pressure: 10 atm

Very good γ-n separation pulse-height discrimination

\( ^3\text{He}(n,p)^3\text{H} \) cross section [b]

\( ^{252}\text{Cf} \) energy spectrum

- 191 keV \(^3\text{H} \) full energy deposition
- 573 keV p full energy deposition

\( ^{252}\text{Cf} \) ungated spectra and gated spectra
Flat-efficiency $4\pi$ neutron detector (ELIGANT – TNF)

Configuration

<table>
<thead>
<tr>
<th></th>
<th>$^3$He counters</th>
<th>Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner ring</td>
<td>4</td>
<td>3.8 cm</td>
</tr>
<tr>
<td>Middle ring</td>
<td>8</td>
<td>7 cm</td>
</tr>
<tr>
<td>Outer ring</td>
<td>8</td>
<td>10 cm</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Neutron multiplicity sorting

see I. Gheorghe talk
Preparatory Gamma Above Neutron Threshold experiment

"Test and calibration of the ELIGANT-TN flat efficiency neutron detection system", IFIN-HH

Proton beam

ELIGANT-TN

Target placed in the center of the detection system: $^{nat}Cu$, $^{nat}Al$

$^3$He counters

28 $^3$He counters mounted on 3 rings:
- Inner ring: 4 counters
- Middle ring: 8 counters
- Outer ring: 16 counters

Polyethylene moderator

Current
1. Beam line
2. Target
3. Collimator
4. Faraday cup

Faraday cup

Cd and polyethylene shielding
Results - $^3\text{He}$ counters spectra

28 counters, mounted on 3 rings:
- Inner ring: 4 counters
- Middle ring: 8 counters
- Outer ring: 16 counters

Neutron – gamma discrimination based on amplitude thresholds set for each $3\text{He}$ counter. Settings optimized for high counting rates (40-50 kHz for entire setup) -> shaping time = 1 us
The ratio between the VME and Scaller numbers gives the **deadtime correction** for each $^3$He counter.

28 counters, mounted on 3 rings:
- Inner ring: 4 counters
- Middle ring: 8 counters
- Outer ring: 16 counters

Results - Monitoring the count rates
The TANDEM proton beam was pulsed by chopping the continuous beam.

Results - Neutron moderation time spectra
Results - Neutron moderation time spectra

- Total neutron spectrum
- 1 neutron events
- 2 neutron events
- 3 neutron events
- 4 neutron events
- 5 neutron events
- 6 neutron events
- 7 neutron events
- 8 neutron events
- 9 neutron events
Current measurement

Proton beam

beam line

target

collimator

Faraday cup

Results – beam monitoring

nat Cu(p,n)

nat Al(p,n)

Proton energy [MeV]

Individual currents/total current

Proton energy [MeV]
Deduced using the ring ratio method

Curves obtained considering the following ratios:
- Inner/Middle
- Inner/Outer
- Middle/Outer
- Average of previous three
- Inner / (Middle+Outer)

Results – average neutron energies

Reaction threshold at 5.803 MeV
Results – neutron detection efficiency

Deduced using the ring ratio method

Curves obtained considering the following ratios:
- Inner/Middle
- Inner/Outer
- Middle/Outer
- Average of previous three
- Inner / (Middle+Outer)

Reaction threshold at 5.803 MeV
Results – $^{\text{nat}}\text{Cu}(p,n)$ cross sections

Cross section:

$$\sigma(E) = \frac{\# \text{interactions}}{\# \text{incident protons} \# \text{target nuclei}}$$

Red curve: IAEA recommendation

Red dots: Present results considering constant 37% efficiency

Black dots: Present results considering ring ratio deduced efficiency

No background subtraction performed yet. Continuous proton beams used for target irradiation.
Results – \textsuperscript{nat}Al(p,n) cross sections

\textbf{Cross section:}

$$\sigma(E) = \frac{\# \text{interactions}}{\# \text{incident protons} \# \text{target nuclei}}$$

\textbf{Black dots:} Present results considering constant 37\% efficiency

No background subtraction performed yet

Continuous proton beams used for target irradiation
• $^{nat}$Cu target (0.9 um thick) irradiation with continuous and pulsed proton beams. Incident energies between 4.5 and 14 MeV (250 keV steps)

• $^{nat}$Al target (1.1 um thick) irradiation with continuous proton beams. Incident energies between 5.8 and 6.75 MeV (10 – 5 keV steps)

• Background measurements with continuous and pulsed proton beams. Empty target frame placed in the center of the detector

• Activation measurements for $^{nat}$Cu+p reactions at 6, 6.5 and 7 MeV incident proton energies.
Collaborators

T. Renstrøm,¹ D. Filipescu,² I. Gheorghe,² T. Glodariu,² M. Krzysiek,²,³ M. Boromiza,⁴ A. Negret,⁴ A. Olacel,⁴ C. Petrone,⁴ F.L. Bello Garrote,¹ H. Berg,¹ F. Furmyr,¹ D. Gjestvang,¹ G. Henriksen,¹,⁵ V.W. Ingeberg,¹ A.-C. Larsen,¹ V. Modamio,¹ L.G. Pedersen,¹ S. Rose,¹ S. Siem,¹ G. Tveten,¹ F. Zeiser,¹ S. Belyshev,⁶ A. Kuznetsov,⁷ K. Stopani,⁷ P. van Beek,⁸ H. Scheit,⁸ D. Symochko,⁸ M. Ciemala,³ M. Kmiecik,³ A. Maj,³ F. Camera,⁹,¹⁰ G. Gosta,⁹ O. Wieland,⁹ T. Ari-izumi,¹¹ and H. Utsunomiya¹¹

¹Department of Physics, University of Oslo, N-0316 Oslo, Norway
²ELI-NP, ”Horia Hulubei” National Institute for Physics and Nuclear Engineering (IFIN-HH), 30 Reactorului, 077125 Bucharest-Magurele, Romania
³Institute of Nuclear Physics Polish Academy of Sciences, PL-31342 Krakow, Poland
⁴”Horia Hulubei” National Institute for Physics and Nuclear Engineering (IFIN-HH), 30 Reactorului, 077125 Bucharest-Magurele, Romania
⁵Norwegian Medical Cyclotron Centre Ltd.
⁶Lomonosov Moscow State University, Department of Physics, Moscow, 119991, Russia
⁷Lomonosov Moscow State University, Skobeltsyn Institute of Nuclear Physics, Moscow, 119991, Russia
⁸Institut für Kernphysik Technische Universität Darmstadt, Germany
⁹University of Milano, Department of Physics, Via Celoria 16, 20133 Milano, Italy
¹⁰INFN Section of Milano, Via Celoria 16, 20133 Milano, Italy
¹¹Department of Physics, Konan University, Okamoto 8-9-1, Higashinada, Kobe 658-8501, Japan
Thank you for your attention