Probing many aspects of the halo structure in Be nuclei
by beating the crap out of it
Shared infrastructure
- TIGRESS gamma-ray detectors
  - High efficiency for S1297
  - Full suppression for S1202
- SHARC vacuum chamber, with modifications
- Madrid dE-E telescope configurations
  - Silicon detectors, often DSSDS
  - Plug into a motherboard
  - Readout with TIGRESS electronics
  - 2 dE1-dE2-Eforward and one E for S1202 to discriminate d,p
  - 4 dE-E for Madrid to discriminate $^{11}$Be (elastic or inelastic), $^{10}$Be (breakup), anything else
- Run as a campaign
  - Also did this last year
Setup
S1297: Structure of $^{10}$Be
• $^{11}$Be(p,d) on CD2 target at $^{10}$Be energy of ~ 10 MeV/u
• Direct reactions
• Populate excited states in $^{10}$Be
• Evaluate (confirm, really) spin with angular distribution of outdoing deuteron
• Measure (or guesstimate, if you’re Byron) wave function composition by spectroscopic factor (absolute cross section)
• 2- state an excited halo?
• Use TIGRESS to tag ~6 MeV states that can’t be resolved by particle spectroscopy by measuring their gamma decay
Started with $^{13}$C(p,d) @ 7 MeV/u to shake down electronics as best as possible

Then went to $^{11}$Be(p,d) @ 9.93 MeV/u

Typically 1.5 to 2 x $10^5$ particles per second

Trigger flaw messed up particle-gamma coincidences for first half of run
Some S1297 results

Excited State Spectrum for $^{11}\text{Be}(p,d)^{10}\text{Be}$

- Entries: 28349
- Mean: 5.292
- RMS: 1.921
Some S1297 results

Gamma deuteron excitation spectrum

Excitation Deut
Entries 21107
Mean 5.537
RMS 1.817

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Value</th>
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<tr>
<td>0.21</td>
<td>0.21645(5)</td>
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<tr>
<td>1.01</td>
<td>5.9611(5)</td>
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<tr>
<td>1.02</td>
<td>5.95839(5)</td>
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<tr>
<td>1.03</td>
<td>6.1803(5)</td>
</tr>
<tr>
<td>1.04</td>
<td>6.2645(5)</td>
</tr>
</tbody>
</table>

Excited states:

- $0^+_1^{10}$Be
- $2^+_1^{10}$Be
- $0^+_2^{10}$Be
- $2^+_2^{10}$Be
- $0^+_0^{10}$Be

Excitation energy range:

- ~0.21 MeV
- ~5.96 MeV
- ~2.896 MeV

Other energy levels:

- 3.367 MeV
- 3.36803(3)
Some S1297 results

Doppler_all_deut:
Entries 15828
Mean 1530
RMS 1440

Ge Doppler corrected All deuteron

10Be
0 MeV

0.21 MeV
2.81 MeV
3.37 MeV
6.245(5)
6.1803(5)
5.9611(5)
5.95839(5)

+1
+2
-2
-1

0
2
1
-2.59 MeV
-5.96 MeV
-2.89 MeV
-3.37 MeV
-3.6803(3)
S1202: Reaction dynamics of halo nuclei, part of an ongoing program
- $^{11}\text{Be} + ^{197}\text{Au}$ at 3.2, 2.9 MeV/u near Coulomb barrier
- Dipole polarizability
- Resonances (unbound states)
- Breakup
- Role of 0.320 MeV excited state
- Measure elastic, inelastic, and breakup channel cross sections, to quantify influence
- Goal: quantify role of these effects
  - Tag inelastic scattering (excitation) with TIGRESS
  - Suppression of elastic cross section relative to simple Rutherford observed in $^{11}\text{Li}$

\[
\begin{align*}
^{10}\text{Be} + \text{n} & \rightarrow 503 \text{ keV} \\
& \rightarrow 320 \text{ keV} \\
^{11}\text{Be} & \\
\text{B(E1)} = 0.116(12) \text{ e}^2\text{fm}^2
\end{align*}
\]
Scaling

\[ t = \left( \pi + \frac{2}{\sin(\theta/2)} \right) \frac{a_0}{h \nu} \]

, \( a_0 = q_t q_p / E \)
Started with $^{12}\text{C}$ at 5 MeV/u for shakedown & efficiency

Took some $^{22}\text{Ne}$ 3.2 MeV/u for further shakedown

Then went to $^{11}\text{Be}(p,d)$ @3.2, then 2.9 MeV/u

Again, typically 1 to 1.8 x10^5 particles per second

Typically 1.5 to 2 x 10^5 particles per second

No electronics problem
Exploring Halo effects in the Scattering of $^{11}\text{Be}$ on Heavy Targets

María José Gª Borge, IEM, CSIC, Madrid
Exploring Halo effects in the Scattering of $^{11}$Be on Heavy Targets

320 keV, ($^{11}$Be: $1/2^- \rightarrow 1/2^+$)

2.9 and 3.6 MeV/u of $^{11}$Be will test Scaling effect
• Both experiments got useful data
• Both experiments were successful from on-line data (S1297, after trigger fixed)
• Both sets of experimenters went home happy
Thank you!

Merci