Three-Nucleon Force (3NF) in Deuteron Disintegration

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Outline

- Introduction and Motivation
- Aim
- Present Status and Future
- End
How many known forces in Nature?

1. Gravity (Newton’s apple)
2. Electromagnetic (Sun light)
3. Weak Nuclear (Fukushima & Chernobyl)
4. Strong Nuclear (Reactor & Bombs)

1935 (Yukawa-theory): ‘Meson exchange between two nucleon’

1947 (Powell & his team): ‘Experimentally found Meson’
Intro & Motivation

...today after almost 6 decades!

Modern NN potential theories:

- Nijm I
- Nijm II
- CD-Bonn
- AV18
- ...

...are able to explain the Interaction between two nucleons accurately e.g. np-scattering

but...........

unable to reproduce three-nucleon system e.g. nd-scattering

High precision data from Los Alamos
W. P. Abfalterer et al., PRL 81, 57 (1998)
...something is missing in the theories! \((V_{th} \neq V_{exp})\).

<table>
<thead>
<tr>
<th>Model</th>
<th>Triton B.E. [MeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nijm I</td>
<td>7.72</td>
</tr>
<tr>
<td>Nijm II</td>
<td>7.62</td>
</tr>
<tr>
<td>Argonne V18</td>
<td>7.62</td>
</tr>
<tr>
<td>Reid-93</td>
<td>7.63</td>
</tr>
<tr>
<td>Experiment</td>
<td>8.48</td>
</tr>
</tbody>
</table>

\[ V_{12} + V_{23} + V_{31} = V_{th} \]

\[ \text{Missing..!!!} \]

\[ 3N \text{ System} \]

\[ V_{exp}. \]
Intro & Motivation

...a new notion: Three-Nucleon Force (3NF)

\[ V_{12} + V_{23} + V_{31} = V_{\text{theory}} \]

\[ 3NF = V_{123} \]

...adding 3NF in original 2NF helps!

<table>
<thead>
<tr>
<th>Model</th>
<th>(^3\text{H} [\text{MeV}])</th>
<th>(^4\text{He} [\text{MeV}])</th>
</tr>
</thead>
<tbody>
<tr>
<td>2NF</td>
<td>7.62</td>
<td>24.2</td>
</tr>
<tr>
<td>2NF +3NF</td>
<td>8.47</td>
<td>28.3</td>
</tr>
<tr>
<td>Experiment</td>
<td>8.48</td>
<td>28.4</td>
</tr>
</tbody>
</table>

additional 3NF

CD-Bonn+**TM99**
AV18+**Urbana XI**

H. Witala et al. **PRL 81, 1183 (1998)**
St. Kistryn et al. **PRC 68, 054004 (2003)**
• 3NF is very small effect: requires high precision data

• Urgent need for enough data base for such study at intermediate energies: will help to develop theories

• Most simple reaction for studying 3NF: $dd$ and $dp$ (breakup and elastic Scattering)

• Different Observables: Measuring Cross-Sections and Analyzing Powers

• BINA detector facility at KVI, The Nederland: best suited for such study, covers large phase-space detection ($4\pi$ solid angle of detection area)
The new $4\pi$ detector, BINA

Big Instrument for Nuclear-polarization Analysis (BINA)
**Present Status and Future**

- KVI has stopped experiments with BINA system: plan to bring it in Krakow, our own accelerator facility (expected by late 2012)

- Analysis of data from previous experiments: current task

- WASA-at-COSY facility, Germany: another option, facility of polarized beam is plus point

**Next Steps:**

- Extend study of 3NF in larger nuclear systems (A>3): 4NF?
- Studying many body systems, Nuclear Matter
- Relativistic and Coulomb Corrections: fine tuning of theories
- Understanding Nuclear Forces with high accuracy may help in useful application for human kind: e.g. in Medical Application
Thank you for attention!
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7. ...

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