$p + d \rightarrow ^3\text{He} + \eta$ cross sections
at 49 and 60 MeV excess energy at WASA-at-COSY

Annika Passfeld$^1$

$^1$Institut für Kernphysik
WWU Münster

DPG-Frühjahrstagung 23.03.2011
Total $p + d \rightarrow ^3He + \eta$ cross sections (only statistical errors):

- Strong energy dependence within the first MeV excess energy caused by a strong final state interaction
- Strong evidence for an $\eta^3He$ bound state
- Excitation function is well known near the production threshold
Motivation

- Larger uncertainties at higher excess energies
- Data from WASA/PROMICE and ANKE show a cross section plateau between 40 and 120 MeV
- 49 MeV GEM data point might indicate a cross section increase above this plateau
- A peak-like structure would be of high interest for studies of the reaction and the final state interaction
- Enhancement can also be an artifact of different normalizations (≈15%)

\[ p + d \rightarrow ^3\text{He} + \eta \] cross sections

SATURNE: SPES-IV (1988)
SATURNE: SPES-II (1996)
COSY: GEM (2000)
A new measurement at 49 MeV is of high interest to clarify the situation.

- Data for the reaction $p + d \rightarrow ^3\text{He} + \eta$ at 60 MeV excess energy were taken with the WASA-at-COSY setup (decay studies).
- To verify the GEM data point additional data were taken at 49 MeV.
- Relative normalization of both data sets possible.
- Data taken at same run period August/September 2009 to minimize systematic uncertainties.
- Preselected data are used for the analysis (preselected on the $^3\text{He}$ nucleus in the Forward Detector).
- For the determination of the differential cross sections the number of $\eta$ events are extracted from the missing mass spectra of different angular ranges.
Number of $\eta$ events

- The background for each $\cos(\vartheta_{\text{CMS}})$ bin is fitted with MC simulations and subtracted.
- The peak is fitted with a Gaussian distribution to determine the $3\sigma$ area.
- The events are counted in this area and are corrected to 100%.
- The extracted $\eta$ numbers are corrected to the detector acceptance.
Normalization

- With known luminosity $L$ and number of $\eta$ events $N_\eta$ the differential cross section for the $i$-th $\cos(\vartheta_{CMS})$ bin can be determined via:

$$\left(\frac{d\sigma}{d\Omega}\right)_i = \frac{1}{4\pi} \frac{N_{\eta,i}}{L}$$

- The total cross section can be calculated by:

$$\sigma_{\text{total}} = \sum_i 2\pi \cdot \Delta \cos(\vartheta_{CMS}) \left(\frac{d\sigma}{d\Omega}\right)_i$$

- Aim: determination of the ratio $\frac{\sigma(49\text{ MeV})}{\sigma(60\text{ MeV})}$
Normalization

- Relative normalization is done via the single pion production:
  \[ p + d \rightarrow ^3\text{He} + \pi^0 \]

- The excess energies for the single pion production are \( Q = 462 \text{ MeV} \) and \( Q = 473 \text{ MeV} \) respectively for the two data samples.

- The phase space volume changes by approximately 1\% only:
  \[
  \sqrt{\frac{Q = 473 \text{ MeV}}{Q = 462 \text{ MeV}}} \approx 1.01
  \]

  \[ \Rightarrow \] The \( \pi^0 \) ratio corresponds to the ratio of the integrated luminosities and is used as normalization factor.

  \[ \Rightarrow \] Absolute normalization to the 60 MeV ANKE cross section.
Normalization

- Preliminary result:
  \[
  \frac{\sigma(49\text{ MeV})}{\sigma(60\text{ MeV})} = 0.98 \pm 0.06
  \]
  \[\Rightarrow \text{No peak-like structure at 49 MeV}\]

- \(\sigma_{\text{ANKE}}(60\text{ MeV}) = (388.1 \pm 7.1) \text{ nb}\)

- The normalization to the 60 MeV ANKE data leads to a preliminary cross section at 49 MeV of
  \(\sigma(49\text{ MeV}) = (379.3 \pm 22.8) \text{ nb}\)

- Additional normalization error of 15\%

- The measured data point agrees well with the described plateau
Comparison of the differential cross sections at $Q = 60$ MeV
Comparison of the differential cross sections at $Q = 40$ MeV and $Q = 49$ MeV
Differential cross sections

Comparison of the differential 49 MeV WASA-at-COSY cross sections to the scaled GEM data

- GEM 49MeV x 0.62
- WASA-at-COSY 49MeV (preliminary)
Total cross sections

- Total cross sections with statistical uncertainties, but without normalization errors
Total cross sections

- Total cross sections with statistical uncertainties and with normalization errors for the 49 MeV data
Conclusion

- Angular distributions of the $p + d \rightarrow ^3\text{He} + \eta$ reaction at 49 and 60 MeV excess energy were extracted.
- With the normalization to the 60 MeV ANKE data and via the single pion production differential and total cross sections were determined.
- There is no peak-like structure in the excitation function at 49 MeV.
- Concerning statistical and systematical uncertainties the new 49 MeV WASA-at-COSY data are not in disagreement with the 49 MeV GEM data:
  - $\sigma_{\text{WASA}}^{\text{prel.}}(49 \text{ MeV}) = (379 \pm 23) \text{ nb} + 57 \text{ nb normalization error}$
  - $\sigma_{\text{GEM}}(49 \text{ MeV}) = (573 \pm 83) \text{ nb} + 69 \text{ nb normalization error}$
- The deviation is due to different normalizations, but the angular distributions are in agreement.
Thank you for your attention!