Few-Body Experimental Projects at TUNL

Diane Markoff
Project 2
Cross Section Measurement of $^2\text{H}(n,\text{np})n$ at 19 MeV and 16 MeV in Symmetric Constant Relative Energy Configurations

Supported by US DoE grants:

UNC    DE-FG02-97ER41042
NCCU   DE-FG02-05ER41380

Computational support: CREST at NCCU
Motivation: The Space Star Anomaly

- Three-nucleon (3N) model of nucleon-nucleon interactions incomplete
- Discrepancies between data and theoretical predictions
- New experiment uses different measurement configuration to alter dependence on systematic effects (thick deuterated target foil, measure np coincidence)

“Space-star Anomaly” in n-d breakup (emitted particles in plane perpendicular to incoming n beam axis)
Also measure coplanar star configuration
Experimental Setup

- SST Neutron Detectors
- Target Chamber
- CST Neutron Detectors
- E-ΔE Charged Particle Telescopes
Data Analysis and Monte Carlo Simulation

**Data Analysis** – particle identification,  
Time of flight analysis for energy,  
detector efficiencies,  
accidentals subtraction,  
cross section calculation

**Monte Carlo Simulation** - To compare experiment with theory,  
one smears point geometry theoretical cross sections to account  
for finite beam, target, and detector geometry, as well as proton  
energy straggling in the target.

Research Scientist – Dr. S. Tajima
Results

Space star  
Coplanar star

16 MeV

Theoretical solid line – CD Bonn Potential  
Error bars – statistical uncertainty; Blue band – systematic uncertainty  
Dashed vertical line – position of the star condition

19 MeV
The space-star anomaly in low energy $nd$ breakup has been confirmed using a different experimental technique than previous measurements.
The NDBU Collaboration
at TUNL

Alex Couture and Tom Clegg
UNC-Chapel Hill
Calvin Howell, Shigeyuki Tajima, Brent Fallin, James Esterline, and Alex Crowell
Duke
Ben Crowe, Diane Markoff, Larry Cumberbatch, and Shigeyuki Tajima
NCCU
Ron Pedroni
NC A&T
Henryk Witała
Jagiellonian University
Photoneutron Asymmetries - $^9\text{Be}$

Data Analysis
Project 2
$^9$Be – Photoneutron Experiment

Polarized $\gamma$-rays from the Duke Univ. H/\gamma S Facility

Measure ratio:

$$R_n = \frac{\sum \text{parallel yield}}{\sum \text{perpendicular yield}}$$

18 Scintillator Detectors
$^9\text{Be} – \text{Experiment Results}$

Graduate Student – B. Davis

$R_n = \frac{\sum \text{parallel yield}}{\sum \text{perpendicular yield}}$

Relatively large ratios can be used to identify beryllium. Indicate interesting nuclear structure. Angular dependence of asymmetries being studied.
Collaborators

B. Davis, M.W. Ahmed, D. Markoff
NCCU and TUNL

H.J. Karwowski, J.R. Tompkins
UNC Chapel Hill and TUNL

J.M. Mueller, L. Myers, S. Stave, C. Smith, H.R. Weller
Duke University and TUNL

TIMELINE: B. Davis Graduates May 2012
paper submitted for publication spring 2012

Additional experiments on U, Th, Pu isotopes
$nn$ and $np$ Quasi-Free Scattering Cross Section via the $nd$ Breakup Reaction at 19 MeV

Experimental Design
Project 2
Motivation

Neutron-deuteron breakup reaction – reaction used to study theoretical nucleon-nucleon potential models and 3-nucleon force contributions

Neutron-neutron quasi-free scattering (nn-QFS)
  discrepancy between data and rigorous 3N calculations

Neutron-proton quasi-free scattering (np-QFS)
  data in good agreement with calculations

- Two previous measurements for nn-QFS:
  \[ E_n = 26 \text{ MeV}; \, ^2\text{H}(d, n) \] and \[ E_n = 25 \text{ MeV}; \, ^3\text{H}(d, n) \]

- Independent verification of discrepancy in new experimental configuration
Proposed Experiment

Measure nn and np QFS cross sections at the same time.

\[ E_n = 19 \text{ MeV} \quad ^2\text{H}(d, n) \]

Use apparatus from star measurements for the np QFS setup.

10 weeks of beam time $\rightarrow$ measure cross sections to a statistical uncertainty of 1 to 1.5%

Goal to achieve overall uncertainty of 2.5% and 4% for the nn and np QFS cross sections
Apparatus Design

Modifications to old target chamber and detector holders
In progress.

Kossi Agbeve – MS Student
Collaborators

Calvin Howell – Duke University and TUNL
Thomas Clegg – UNC Chapel Hill and TUNL
Werner Tornow - Duke University and TUNL
Ben Crowe - NCCU
Diane Markoff – NCCU
Kossi Agbeve – NCCU MS student

Starting Spring 2012 NCCU Undergraduates
Brogan Thomas
Haley Harrison
Edward Long
Few-Body Experimental Projects at TUNL
Project 2

nd breakup – space star and coplanar star cross section measurements – 16 and 19 MeV
(completed)
Beryllium-9 ($\gamma$,n) asymmetry measurements
(analysis in final stages)
nn and np QFS cross section measurements in nd breakup at 19 MeV
(project in design phase)