Study of Neutron Resonances via Precision $\gamma n$ Measurements

- Measurement goal: Describe excited nucleon states as a means to understand strongly interacting matter
- QCD describes systems of interacting quarks but is challenged by effects that dress the interactions
- Need measurements for both proton and neutron targets to disentangle different isospin contributions
  (neutron measurements sorely lacking)

This first determination of neutron couplings at the pole positions significantly improves the world data

$g_{13}$ increases world data by x3

<table>
<thead>
<tr>
<th>Resonance</th>
<th>Coupling</th>
<th>SAID Fits Modulus, phase</th>
<th>PDG 2016 BW</th>
</tr>
</thead>
<tbody>
<tr>
<td>N(1440)1/2*</td>
<td>$A_{1/2}$ (n)</td>
<td>0.065±0.005, 5°±3°</td>
<td>0.040±0.010</td>
</tr>
<tr>
<td>N(1535)1/2*</td>
<td>$A_{1/2}$ (n)</td>
<td>-0.055±0.005, 5°±2°</td>
<td>-0.075±0.020</td>
</tr>
<tr>
<td>N(1650)1/2*</td>
<td>$A_{1/2}$ (n)</td>
<td>0.014±0.002, -30°±10°</td>
<td>-0.050±0.020</td>
</tr>
<tr>
<td>N(1720)3/2*</td>
<td>$A_{1/2}$ (n)</td>
<td>-0.016±0.006, 10°±5°</td>
<td>-0.080±0.050</td>
</tr>
<tr>
<td>N(1720)3/2*</td>
<td>$A_{3/2}$ (n)</td>
<td>0.017±0.005, 90°±10°</td>
<td>-0.140±0.065</td>
</tr>
</tbody>
</table>

CLAS “$g_{13}$” experiment: $\gamma d \rightarrow \pi^- p(p)$
8400 bins: $E_\gamma$ [0.445 – 2.510 GeV], $\cos \theta_{\pi^- n}$: [-0.72 – 0.92]

FSI corrections applied to extract $\gamma n$ from $\gamma d$

P.T. Mattione et al. (CLAS Collaboration), PRC 96, 035204 (2017)
Measurements of $ep \to e'p\pi^+\pi^-$ Cross Sections with CLAS at $1.40 \text{ GeV} < W < 2.0 \text{ GeV}$ and $2.0 \text{ GeV}^2 < Q^2 < 5.0 \text{ GeV}^2$

Fully integrated $\pi^+\pi^-p$ electroproduction cross sections off protons

- First results on nine independent 1-fold differential and fully integrated $\pi^+\pi^-p$ cross sections in this $W/Q^2$ domain

- Successful data description with JM17 model should allow extraction of most resonance electrocouplings for $Q^2$ from 2.0 - 5.0 GeV$^2$ for the first time and for validation of new baryon states

- Relative growth of resonant contributions with photon virtuality $Q^2$ emphasizes the capabilities of obtaining resonance electrocouplings in the full $Q^2$-range covered by the measurements


Description of nine 1-fold differential cross sections within JM17 model:

- Full JM17
- Non-resonant contributions
- Resonant contributions

$W=1.71 \text{ GeV}, Q^2=3.2 \text{ GeV}^2$

$W=1.51 \text{ GeV}$

Full $\pi^+\pi^-p$ integrated cross section

Resonant contribution and its uncertainties