A data selection and reduction for asymmetry analysis in the NPDGamma experiment

David Blyth\textsuperscript{1} dblyth@asu.edu

\textsuperscript{1}Arizona State University

2013 Fall Meeting of the APS Division of Nuclear Physics
The $np \rightarrow d\gamma$ asymmetry

- The NPDGamma experiment measures asymmetry in gamma emission from the $np \rightarrow d\gamma$ reaction
- Goal of one part in $10^8$ for PV asymmetry
- PV asymmetry unambiguously related to the DDH pion coupling constant
- Pulsed cold neutron beam at SNS is polarized and captures on a liquid parahydrogen target
The \( np \rightarrow d \gamma \) asymmetry

- The NPDGamma experiment measures asymmetry in gamma emission from the \( np \rightarrow d \gamma \) reaction.
- Goal of one part in \( 10^8 \) for PV asymmetry.
- PV asymmetry unambiguously related to the DDH pion coupling constant.
- Pulsed cold neutron beam at SNS is polarized and captures on a liquid parahydrogen target.

David Blyth dblyth@asu.edu
Arizona State University
A data selection/reduction for NPDG
The $np \rightarrow d\gamma$ asymmetry

- The NPDGamma experiment measures asymmetry in gamma emission from the $np \rightarrow d\gamma$ reaction.
- Goal of one part in $10^8$ for PV asymmetry.
- PV asymmetry unambiguously related to the DDH pion coupling constant.
- Pulsed cold neutron beam at SNS is polarized and captures on a liquid parahydrogen target.
Measuring the asymmetry

- CsI array with $3\pi$ acceptance in four rings surrounds LH$_2$ target
- Beam choppers select neutrons of single wavelength at any given time by eliminating overlap
- RF spin rotator and chopped beam allow efficient flipping of polarized neutrons to produce an 8-pulse spin sequence ($\uparrow\downarrow\downarrow\uparrow\uparrow\uparrow\uparrow\downarrow$)
  - Spin sequence and symmetry of detector array allow for asymmetry measurement while eliminating some systematic effects
Measuring the asymmetry

- CsI array with $3\pi$ acceptance in four rings surrounds LH$_2$ target
- Beam choppers select neutrons of single wavelength at any given time by eliminating overlap
- RF spin rotator and chopped beam allow efficient flipping of polarized neutrons to produce an 8-pulse spin sequence ($\uparrow\downarrow\downarrow\uparrow\uparrow\uparrow\downarrow$)
  - Spin sequence and symmetry of detector array allow for asymmetry measurement while eliminating some systematic effects
Measuring the asymmetry

- CsI array with $3\pi$ acceptance in four rings surrounds LH$_2$ target
- Beam choppers select neutrons of single wavelength at any given time by eliminating overlap
- RF spin rotator and chopped beam allow efficient flipping of polarized neutrons to produce an 8-pulse spin sequence ($\uparrow \downarrow \downarrow \uparrow \uparrow \uparrow \downarrow$)
  - Spin sequence and symmetry of detector array allow for asymmetry measurement while eliminating some systematic effects
Parameterization of detector signals

\[ S_{ij}^{\uparrow \downarrow} = D_i N_j^{\uparrow \downarrow} (1 \pm \varepsilon_i) + C_i \]  

(1)

Conjugate detector:

\[ S_{(i+\pi)j}^{\uparrow \downarrow} = D_{(i+\pi)} N_j^{\uparrow \downarrow} (1 \mp \varepsilon_i) + C_{(i+\pi)} \]  

(2)

- Signal \( S_{i,j}^{\uparrow \downarrow} \) for detector \( i \), time \( j \) is dependent on detector gain/efficiency \( D \), neutron capture rate \( N \), raw asymmetry \( \varepsilon \), and a slowly changing pedestal \( C \)

- \( S_i^{\uparrow \downarrow} \) and \( S_{i+\pi}^{\uparrow \downarrow} \) are combined to extract \( \varepsilon \) independent of \( D \) and \( N \)

- \( C \) still must be accounted for (e.g. talks by S. Kucuker DE.00002 and J. Fry DE.00003)
Parameterization of detector signals

\[ S_{ij}^{\uparrow\downarrow} = D_i N_j^{\uparrow\downarrow} (1 \pm \varepsilon_i) + C_i \]  

(1)

Conjugate detector:

\[ S_{(i+\pi)j}^{\uparrow\downarrow} = D_{(i+\pi)} N_{j}^{\uparrow\downarrow} (1 \mp \varepsilon_i) + C_{(i+\pi)} \]  

(2)

- Signal \( S_{i,j}^{\uparrow\downarrow} \) for detector \( i \), time \( j \) is dependent on detector gain/efficiency \( D \), neutron capture rate \( N \), raw asymmetry \( \varepsilon \), and a slowly changing pedestal \( C \)

- \( S_{i}^{\uparrow\downarrow} \) and \( S_{i+\pi}^{\uparrow\downarrow} \) are combined to extract \( \varepsilon \) independent of \( D \) and \( N \)
  - \( C \) still must be accounted for (e.g. talks by S. Kucuker DE.00002 and J. Fry DE.00003)
Beam requirements

- Analysis requires us to understand $\varepsilon$ to extract asymmetry from prompt gamma emission: $\varepsilon (A_\gamma, P, \omega, \ldots)$
  - $\varepsilon$ function of polarization and spin rotator (SR) efficiency among other factors; these factors must be known
- Existence of “leakage neutrons” (typically $\sim 1\%$) requires that
  - beam fluctuations are small
  - chopper phases are consistent

in order to minimize uncertainty in $\varepsilon$ dependencies
Beam requirements

▶ Analysis requires us to understand $\varepsilon$ to extract asymmetry from prompt gamma emission: $\varepsilon(A_\gamma, P, \omega, \ldots)$
  ▶ $\varepsilon$ function of polarization and spin rotator (SR) efficiency among other factors; these factors must be known
▶ Existence of “leakage neutrons” (typically ~1%) requires that
  ▶ beam fluctuations are small
  ▶ chopper phases are consistent

in order to minimize uncertainty in $\varepsilon$ dependencies
Beam fluctuations

- Significant beam fluctuations occur during normal operation arising from accelerator diagnostics, as well as from occasional abnormalities
- A 1% cut is applied to variations in monitor pulse integral
Chopper phase variations

- Variation in chopper phase can arise from degradation of the synchronization signal from the accelerator.
- To place a limit on chopper phase variations, linear correlation with a reference pulse is quantified.
- The reference pulse is created by averaging monitor signals during normal chopper operation.

David Blyth dblyth@asu.edu
Arizona State University
A data selection/reduction for NPDG
Variation in chopper phase can arise from degradation of the synchronization signal from the accelerator.

To place a limit on chopper phase variations, linear correlation with a reference pulse is quantified.

The reference pulse is created by averaging monitor signals during normal chopper operation.
Chopper phase variations

 Variation in chopper phase can arise from degradation of the synchronization signal from the accelerator.

 To place a limit on chopper phase variations, linear correlation with a reference pulse is quantified.

 The reference pulse is created by averaging monitor signals during normal chopper operation.
Chopper phase variations, continued

- Correlation coefficient defined as
  \[ r_{xy} = \frac{\sigma_{xy}^2}{\sigma_x \sigma_y} \]  
  \[ (3) \]

- Interpreted as the amount of variance of signal \( y \) accounted for by reference \( x \)

- Chopper phase variations can be limited by modeling the form of the neutron pulse, and calculating \( r_{xy} \) for a certain chopper phase.

- Significant phase shifts occur in only 0.01% of data
Chopper phase variations, continued

- Correlation coefficient defined as

\[ r_{xy} = \frac{\sigma_{xy}^2}{\sigma_x \sigma_y} \]  

- Interpreted as the amount of variance of signal \( y \) accounted for by reference \( x \)

- Chopper phase variations can be limited by modeling the form of the neutron pulse, and calculating \( r_{xy} \) for a certain chopper phase.

- Significant phase shifts occur in only 0.01\% of data

David Blyth

dblyth@asu.edu

Arizona State University

A data selection/reduction for NPDG
Correlation coefficient defined as

\[ r_{xy} = \frac{\sigma_{xy}^2}{\sigma_x \sigma_y} \]  

Interpreted as the amount of variance of signal \( y \) accounted for by reference \( x \)

Chopper phase variations can be limited by modeling the form of the neutron pulse, and calculating \( r_{xy} \) for a certain chopper phase.

Significant phase shifts occur in only 0.01% of data
Before and after

- In total, data cuts result in a loss of about 15% of the $np \rightarrow d\gamma$ asymmetry data.
- The resulting asymmetry distribution is well approximated by a Gaussian function.
Summary

- The symmetry of the NPDGamma detector combined with pulse-by-pulse spin sequencing suppresses significant systematic effects and non-Poisson random contributions:
  - Electronic asymmetry
  - Al beta-decay asymmetry
  - Beam power fluctuations
- Data selection places limitations primarily on large beam power fluctuations, and to a lesser degree chopper phase variations to ensure the validity of polarimetry, etc.
- Systematics studies then boil down to few significant contributions, such as
  - Al prompt asymmetry (Z. Tang PG.00001, this session)
  - Neutron polarization (M. Musgrave DE.00004)
  - Depolarization on orthohydrogen in target (C. Gillis DE.00005)