The NPDGamma Experiment

Measurement of Parity-Violating Gamma-ray Asymmetry on Hydrogen with Polarized Cold Neutrons

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Outline

- Motivation and Theory
- Experimental Setup
- Targets
- Analysis Procedure
- Status
Motivation and Theory

- Measure the parity-violating (PV) $\gamma$-ray asymmetry, $A_\gamma$, in the reaction $n + p \rightarrow d + \gamma$ to a precision of $1 \times 10^{-8}$ in order to provide a sensitive test of hadronic weak interaction models.
- In general, the PV asymmetry in a measurement can be expressed as an expansion in terms of the coupling constants:

$$A = a_\pi^1 f_\pi^1 + a_\rho^0 h_\rho^0 + a_\rho^1 h_\rho^1 + a_\rho^2 h_\rho^2 + a_\omega^0 h_\omega^0 + a_\omega^1 h_\omega^1$$
The asymmetry depends almost exclusively on the weak pion-nucleon coupling $f_\pi$. NPDGamma $\Rightarrow$ Two-Body System- measures an asymmetry with a simple relation to $f_\pi$ - providing a theoretically clean interpretation of the experiment.
The main NPDGamma observable is the up-down asymmetry in the angular distribution of gamma-rays with respect to the neutron spin direction. 

\[
\frac{d\sigma}{d\Omega} \propto \frac{1}{4\pi} \left( 1 + A_\gamma \cos \theta \right)
\]

\[
\vec{s}_n \cdot \vec{k}_\gamma
\]

\[
\vec{s}_n \cdot \vec{k}_\gamma > 0 \implies \text{up}
\]

\[
\vec{s}_n \cdot \vec{k}_\gamma < 0 \implies \text{down}
\]

\[
A_\gamma \approx -0.107 f_\pi^1 \quad \Rightarrow \quad f_\pi\]

ILL and LANSCE provide \(A_\gamma \leq 2 \times 10^{-7}\). SNS–FOM(NP\(^2\)) \(\times 100\) improved, expected to be in the range of 0 to \(10 \times 10^{-8}\).
Spallation Neutron Source at ORNL

- 1.4 GeV pulsed protons, 60Hz, 1 MW power
- Hg Spallation target $\rightarrow$ neutrons
- $\text{H}_2$ moderator $\rightarrow$ cold neutrons
- 17 m SM guide, curved
Experimental Setup
The NPDG Experiment at FnPB
Super Mirror Polarizer

- High Neutron Polarization ~95%
- Stable Polarization
RF Spin Flipper

- Creates an oscillating magnetic field tuned to the Larmor frequency of the neutrons.
Detector Array

- 48 CsI(Tl) scintillator crystals coupled to 3 inch vacuum photodiodes
- 4 rings of 12 CsI (Tl) Detectors 15x15x15 cm$^3$ each
- Covers a solid angle of $3\pi$
- High Count Rate → Current mode gamma detection
- The gain is provided by low noise solid state preamplifiers
Commissioning Targets

- B$_4$C → For counting statistics limit
- $^6$Li → For background and shielding studies
- $^{35}$Cl → Commission the entire system
  - to demonstrate our ability to measure a large and well known PV asymmetry
- Al → Largest source of background
  - measure the PV asymmetry for window subtraction for LH$_2$ target
LH$_2$ Target

- 16L liquid para-hydrogen vessel in a vacuum
- 30 cm diameter x 30 cm long
- Target must be pure para-hydrogen

\[ \text{to avoid} \]

Beam Depolarization
and Reflection
Scattering from ortho-$\text{H}_2$ leads to depolarization. Target must be pure Para-Hydrogen.

MCNP calculation of neutron beam intensity in liquid hydrogen target

Distance (cm)

Distance (cm)

Distance (cm)

Distance (cm)

Pure Ortho - $\text{H}_2$

Pure Para - $\text{H}_2$
Analysis Procedure

- PV asymmetry → Essentially seen in a difference of the number of gamma-rays going up and down
- Check for possible left-right asymmetry

\[ A_{raw} = 1 + A_{\gamma, UD} \cos \theta + A_{\gamma, LR} \sin \theta \]
Analysis Procedure Cont.

- Dynamic Pedestal Subtraction
  - dilution from beta-delayed gammas

- Geometrical factors
  - cosine dependence of cross section

- Asymmetry from prompt Al gammas

- Beam polarization
  - ToF adjustment prior to asymmetry calculation

\[
A_{\text{raw}} = \frac{1}{2} \left( \frac{Y_{i}^{\uparrow} - Y_{j}^{\uparrow}}{Y_{i}^{\uparrow} + Y_{j}^{\uparrow}} + \frac{Y_{j}^{\downarrow} - Y_{i}^{\downarrow}}{Y_{j}^{\downarrow} + Y_{i}^{\downarrow}} \right)
\]

Y-count rate

\( \uparrow \)-spin up

\( \downarrow \)-spin down

i and j—conjugate det.
Status

- Beam profile measured
- Flux confirmed
- Detailed studies of new shielding material performed
- Polarization of beam established
- Precision measurements of detector locations completed
- Al and Chlorine data collection completed
  - Preliminary Data Analysis completed
Status Cont.

- LH$_2$ target set-up completed
- Target-cooled down and filled successfully
- Neutron Beam on LH$_2$ target
- Production Hydrogen Data
Talks

- Nadia Fomin—Measurement of the Parity-Violating directional Gamma-ray Asymmetry in Polarized Neutron Capture on 35Cl

SESSION D11-EMBASSY F

- Elise Martin—Neutron Beam Characterization for the NPDGamma Experiment at SNS
- Matthew Musgrave—Neutron Polarization Measurements with a 3He Spin Filter for the NPDGamma Experiment
- Chad Gillis—A liquid parahydrogen target for the NPDGamma Experiment
- Kyle Grammer—Calculation of the Detector Solid Angles and Geometrical Factors for the NPDGamma Experiment