Photodisintegration of Deuteron in Low-energy region: H1γS Frozen Spin Target (HIFROST)

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Deuteron Photodisintegration Program in Low Energy at HI\(\gamma\)S/TUNL—currently active progress

- GDH sum rule using \(d(\gamma,n)p\) between \(E_\gamma=4\) MeV and 20 MeV

- Measurement of \(P_y\) in \(d(\gamma,n)p\)

- Measurement of the tensor analyzing power in deuteron photodisintegration between \(E_\gamma=4\) MeV and 20 MeV
Gerasimov-Drell-Hearn Sum Rule

\[ \int_{\omega_2}^{\infty} \frac{\sigma_P^{\text{tgt}} - \sigma_A^{\text{tgt}}}{\omega} \ d\omega = -4S_{\text{tgt}} \pi^2 \alpha \left( \frac{\kappa_{\text{tgt}}}{m_{\text{tgt}}} \right)^2 \]

Target \quad \kappa \quad \int_{\text{GDH}}
\begin{array}{c|c|c}
\text{p} & 1.79 & 204.0 \mu b \\
\text{n} & -1.91 & 232.0 \mu b \\
\text{d} & -0.14 & 0.6 \mu b
\end{array}

\[ \int_{\omega_2}^{\infty} \frac{\sigma_P^d - \sigma_A^d}{\omega} \ d\omega = \int_{\omega_2}^{\omega_\pi} \frac{\sigma_P^d - \sigma_A^d}{\omega} \ d\omega + \int_{\omega_\pi}^{\omega_{\text{max}}} \frac{\sigma_P^d - \sigma_A^d}{\omega} \ d\omega + \int_{\omega_{\text{max}}}^{\infty} \frac{\sigma_P^d - \sigma_A^d}{\omega} \ d\omega = 0.6 \]

E_{np} \sim 9 \text{ MeV}

\( \sigma_P - \sigma_A \sim \text{maximal} \)
\( \sigma_P - \sigma_A \sim 0 \)
\( \sigma_P - \sigma_A < 0 \)

Area Bounded by Curve = Contribution to Sum Rule

\text{Arenhovel et al}
Gerasimov-Drell-Hearn Sum Rule

The measurements:

\[
\frac{d\sigma}{d\Omega} = \frac{d\sigma_0}{d\Omega} \left[ 1 - P_1^d P_c^T l_0^c \left( \theta \right) + P_2^d T_2^c \left( \theta \right) \right]
\]
Circular photon polarization
Longitudinal target polarization

\[
\frac{d\sigma}{d\Omega} = \frac{d\sigma_0}{d\Omega} \left[ 1 + P^{\gamma} \Sigma^l \left( \theta \right) \cos 2\varphi + P_2^d T_2^l \left( \theta \right) + P_1^{\gamma} \right] \left\{ P_1^d T_1^l \left( \theta \right) \sin 2\varphi + P_2^d T_1^l \left( \theta \right) \cos 2\varphi \right\}
\]
Linear photon polarization
Longitudinal target polarization
Experiments

- Liquid Scintillator
- $E_\gamma < 20 \text{ MeV}$

HIFROST
High Intensive Gamma Source (HIGS) in Duke Free-Electron Laser Laboratory (DFELL)
High Intensive γamma Source (HIγS)

- Free electron laser from 192 to 780 nm
- Compton backscattering to produce γ-ray beam up to 100 MeV
- Intracavity scattering leads to a very intense beam (~10⁷ γ/s)

- Monoenergetic beam (ΔE/E=0.7~4.0% with collimators)
- Beam can be linearly or circularly polarized
Blowfish detector cell

- 88 BC-505 liquid scintillator
- 8-evenly spaced arms in $\phi$
- 11-evenly spaced in $\theta$
- cover $\frac{1}{4}$ of $4\pi$
HIγS FROzen Spin Target (HIFROST)

- Originally designed by T. Niinikoski in 1970’s
- Used at CERN and GKSS in Germany in early 2000’s
- Moved to in 2011 and modified by UVa (270mK)
- Moved to Duke in 2013 (190mK)
- Moved back to UVa in 2015 (150mK)
HIγS FROzen Spin Target (HIFROST) at Duke/TUNL

target cryostat
HİγS FROzen Spin Target (HIFROST) at Duke/TUNL
HI\gamma S FROzen Spin Target (HIFROST) at Duke/TUNL
HIγS FROzen Spin Target (HIFROST) at Duke/TUNL

- Jan 2014: a holding coil was damaged
  -> need a new IVC and capillary for LHe, rewinding a holding coil, testing/mapping
- Feb 2014: OVC damaged during fridge assembly
  -> fixed by JLab
- Jul 2014: designed and built 3He recovery manifold
- Jul 2014: mechanical pump (evap) failures
H\text{I} \gamma S \text{ FROzen Spin Target (HIFROST)} \text{ at Duke/TUNL}
HI\gamma S FROzen Spin Target (HIFROST) at Duke/UVa

- Oct 2014: dilution reached 190mK
- Jan 2015: the new LHe capillary on IVC on was crushed during assembly
  -> need a new IVC and winding a coil, testing/mapping, power training
- Mar/April 2015: only dilution to 150mK,
  found external head loading,
  -> moved fridge back to UVa
- Jun 2015 – resolved 4K heat leak problem
- Nov 2015 – finish rebuilding and testing/mapping a holding coil
- Dec 2015 – cooled the holding coil to superconducting temperatures
- Jun 2016 – trained the coil to 24.5A though holding coil with fridge
- Jul 2016 – installed dual cold trap in gas flow system at Duke
- Aug 2016 – completed replacing a mechanical pump for 1K pot at Duke
Frozen Spin Polarized Target Commissioning Results Summary

✓ All vacuum systems operational
✓ Cryogenic liquid transfer established
✓ 1 K evaporative precooler online
✓ Holding magnet ramped to 0.5 T
✓ NMR installed and tested
✓ DNP microwave generator tested
✓ d-butanol material irradiated and polarized
✓ Polarizing magnet ramped to 2.5 T
✓ GDH, $P_{zz}$ and FSP experiments approved
✓ Dilution below 100 mK (frozen spin target)
Gerasimov-Drell-Hearn Sum Rule target: HIFROST

Current Status:
  Two cooldowns at HIGS in spring
  Revealed issues with heat leaks, magnet shorts and pumping speeds

Microwave system:
  Appeared that COBER PS not putting out enough power. Subsequently determined that power meter malfunctioning power meter

NMR System:
  All components ready
  Tuning required

Polarizing Magnet:
  Fringe field range measured
  5 G limit for pacemakers established
Gerasimov-Drell-Hearn Sum Rule

(Other experimental preparations)

Detectors:
All damaged Blowfish cells repaired
Characterize response with monoenergetic neutrons
Realign and check Blowfish array
Develop procedures for moving/rotating Blowfish

Data Acquisition:
Ready
Used in July with subset of detectors
Two parallel/redundant channels
  FADC based
  “traditional” two-gate system

Analysis:
Follow procedures of previous Blowfish experiments
GEANT-4 simulation packages ready
  target new
  Blowfish rotated
Future Work

Target returned to Duke in autumn 2016
Dilution optimization attempts below 150 mK
Target material loaded into refrigerator
Data run (~100 hours beamtime allotted)
Analysis, writeup and publication of results

AIM TO FINISH FIRST RUN BY JUNE 2017