Status Report: E05-103: Low Energy Deuteron Photodisintegration

Jackie Glister

Dalhousie University & Saint Mary's University

Hall A Collaboration Meeting
December 13, 2007

Spokespeople: R. Gilman, A. Sarty & S. Strauch
Ph.D. Students: J. Glister & G. Ron
Undergraduate Students: J. Dumas, E. McCullough & Y. Rousseau

Deuteron Photodisintegration at Low Energies

- At lower photon energies, theoretical calculations based on meson-baryon degrees of freedom give a good description of cross-section and polarization observables
- Currently, the best model comes from Schwamb and Arenhövel (complete calculation is solid line in figures), where modern NN potentials and relativistic corrections have been incorporated

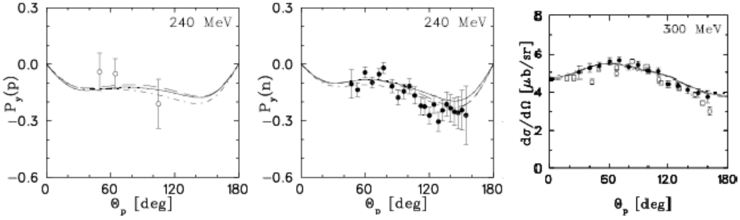
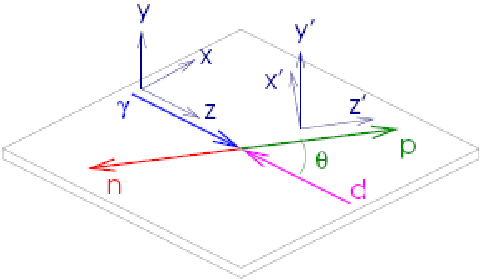


Figure: Nucl. Phys. **A690**, 682 (2001)

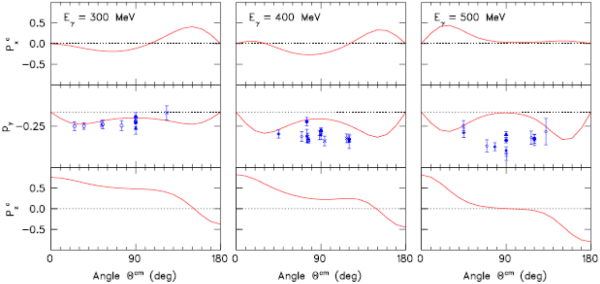
Observables

- $P^c_{x'} \Rightarrow$ transferred polarization in reaction plane, $\perp$ to $\vec{p}$
  Real part of sum of amplitudes
- $P_y \Rightarrow$ induced polarization, $\perp$ to reaction plane
  Imaginary part of same sum of amplitudes
- $P^c_{z'} \Rightarrow$ transferred polarization in reaction plane, $\parallel$ to $\vec{p}$
  Difference of amplitudes squared



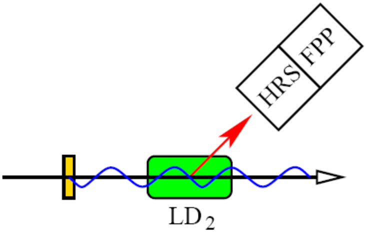
Discrepancy in Proton Polarization Observables

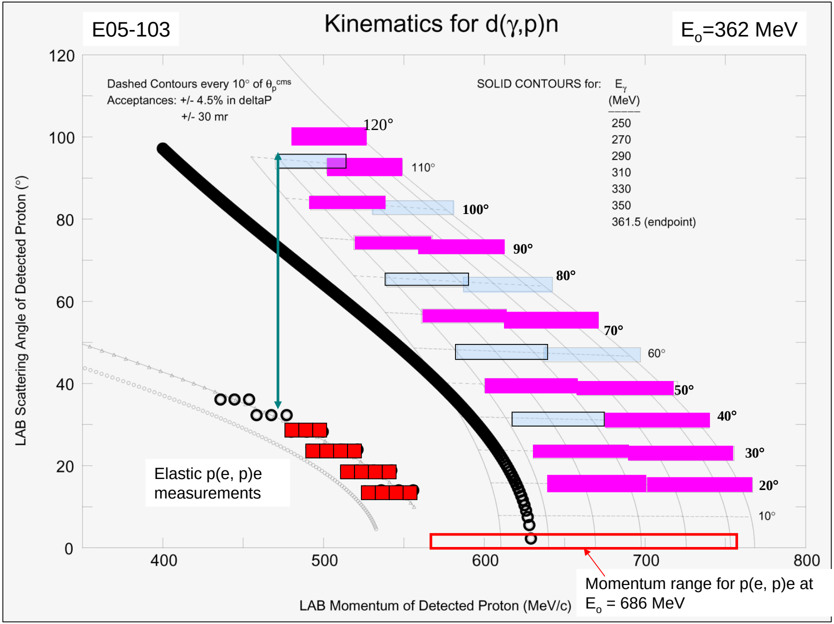
- As incident photon energy grows, a disagreement between world data and the calculation for P_y emerges around $\theta_{cm} = 90^o$
- No data for $P_x^{c'}$ and $P_z^{c'}$ in this energy region
- Motivation of experiment was to provide high-precision polarization data in the 300-400 MeV region to help resolve whether the problem lies with the data or the calculation



Deuteron Photodisintegration Reaction

- E_o = 361.7 MeV, giving photon energy endpoint of 361.2 MeV
- Bremsstrahlung photon production using copper radiator with 4% and 5% of a radiation length thickness
- Circularly polarized photon incident on 15 cm LD2
- Singles measurement with proton momentum kept above pion production threshold
- FPP carbon analyzer thickness increased with proton momentum: S2 + (0.75”, 2.25” and 3.75”)




E05-103
Kinematics for d(γ,p)n
E$_o$=362 MeV
Dashed Contours every 10° of θ_p^{cms}
Acceptances: +/- 4.5% in deltaP
+/- 30 mr
SOLID CONTOURS for: E_γ (MeV)
250
270
290
310
330
350
361.5 (endpoint)
120°
110°
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
Elastic p(e, p)e measurements
Momentum range for p(e, p)e at E_o = 686 MeV
LAB Scattering Angle of Detected Proton (°)
LAB Momentum of Detected Proton (MeV/c)
0
20
40
60
80
100
120
400
500
600
700
800

Electron Beam Polarization

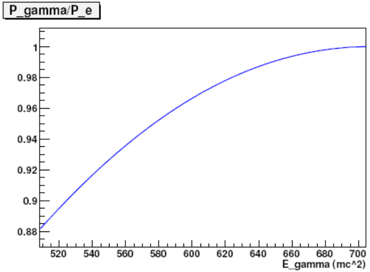
- Energy too low to use standard Hall A Moller polarimeter
- Mott measurements at injector: 80-85%
- Longitudinal polarization in the hall given by
  $P_z = P_{Mott} \times \cos(\theta_{wien} + \theta_A)$
- $\theta_A = 170.4^o$ calculated using program LAUNCHV8
- Polarization of 38 - 41%, except for last setting ($\theta_{cm} = 120^o$) when the Wien angle was changed and polarization was 72%

Photon Beam Polarization

Circular photon polarization is given by (Phys. Rev. C 110, 589 (1958)):

$$P_\gamma^c = \frac{P_e k(\epsilon_1 + \frac{\epsilon_2}{3})}{\epsilon_1^2 + \epsilon_2^2 - \frac{2\epsilon_1}{3\epsilon_2}} \quad (1)$$

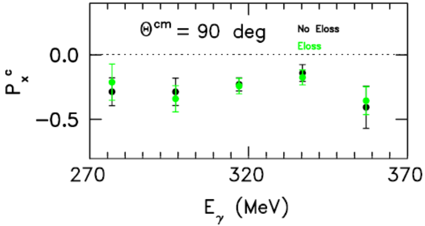
where: k = photon energy, ϵ_1/ϵ_2 = initial/final electron energy ($m_e c^2$). For each angular setting, P_γ/P_e varies between 0.88 and 1.00, so the fraction is calculated on an event by event basis.



Energy Loss Corrections

Proton energy loss has several contributions (with target cavity normalized to 1):

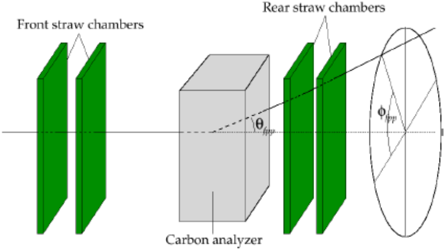
- Target cavity: 1
- Target capsule: 0.06
- Target endcaps: 0.01
- Kapton entrance window: 0.01
- Titanium exit window: 0.01
- Air: 0.02

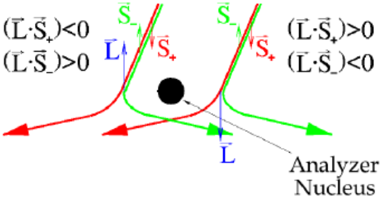


Energy loss is determined event by event by calculating the total pathlength through the target cavity, moving events to bins of higher photon energy. Small effect as seen in Figure, all other contributions (1/10th the size) are negligeable.

Extracting Polarization Observables

The spin-orbit interaction between the proton and carbon analyzer nucleus results in an asymmetry in the azimuthal scattering angle, ϕ_{fpp}. Left-right asymmetry gives the vertical component, P_x^{fpp}, while the up-down asymmetry gives the horizontal component, P_y^{fpp}.





Analyzing Power

- The strength of the spin-orbit interaction, or analyzing power, is needed to extract polarizations
- Low Q^2 ep elastic scattering data were taken to parameterize the analyzing power at low proton momentum
- McNaughton parameterization: 3 coefficients (a,b & c) fit to data ($r = \sin\theta_{fpp}$):
  $A_c(\theta_{fpp}, T_p) = \frac{ar}{1+br^2+cr^4}$
- New parameterization uses extra coefficient (d):
  $A_c(\theta_{fpp}, T_p) = \frac{ar}{1+br^2+cr^4+dr^6}$

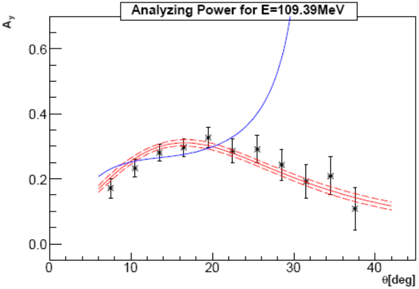
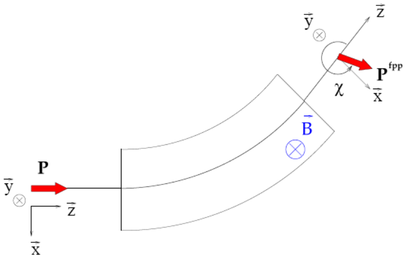
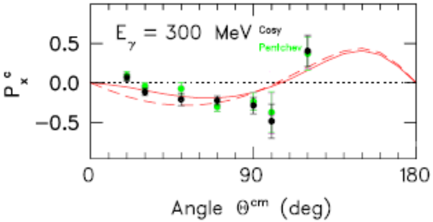


Figure: G. Ron

Spin Precession

- Simple dipole approximation - seen in Figure
- Pentchev approximation
- Full COSY spin rotation
- Polarization observables calculated using Pentchev and COSY methods agree within statistical error bars, so Pentchev approximation can be used to evaluate systematic error of spin rotation





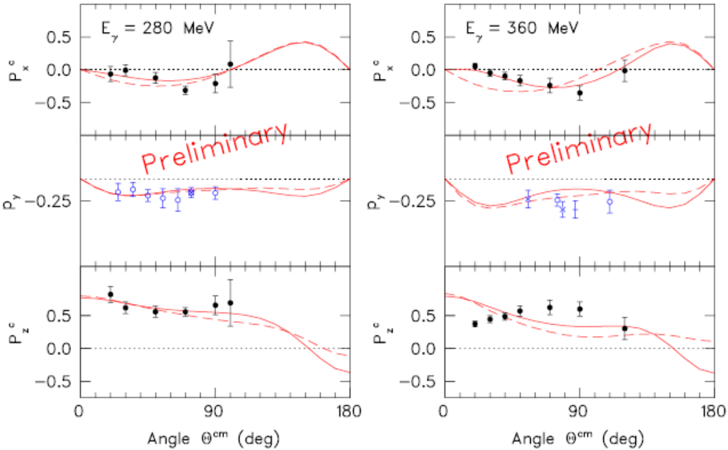
Systematics

- Uncertainties associated with spin rotation were calculated when the FPP was in the right arm and for a higher momentum range, they will be conservatively doubled
- Systematics of FPP angular resolution, beam polarization, beam position, analyzing power parameterization, kinematic cuts, false asymmetries and background subtraction will also be considered

Variable	Shift
θ_{fpp}	2 mrad
ϕ_{fpp}	2 mrad
θ_{fp}-θ_{tg}	2×7 mrad
ϕ_{fp}-ϕ_{tg}	2×0.3 mrad
$(\phi_d \| y_{tg})$	2×0.038
$(\phi_d \| \phi_{tg})$	2×0.082
$(\Delta\phi_d \| y_{tg})$	2×0.105
$(\Delta\phi_d \| \phi_{tg})$	2×0.111
Mott stat	1.19 - 1.77% (abs)
Mott sys	0.91 - 1.02% (abs)

Results

- Uncertainties are statistical only; world data for P_y shown in blue
- Curves are Schwamb and Arenhövel, dashed are more recent (interactions in propagating πNN-system treated non-perturbatively, as opposed to only approximately)



Summary

- Transferred polarization results are essentially finalized, systematic error analysis underway
- Both P_x^c and P_z^c are in excellent agreement with the calculations of Schwamb and Arenhövel at the lowest energy
- As energy grows, it becomes clear that P_x^c has better agreement with the older calculation (solid line), while P_z^c appears to have a different shape from both curves
- Induced polarization available once false asymmetries are parameterized