E08-008: Exclusive Study of Deuteron Electrodisintegration near Threshold

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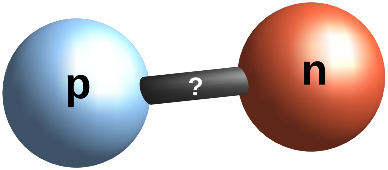
Outline

Questions

The major question:

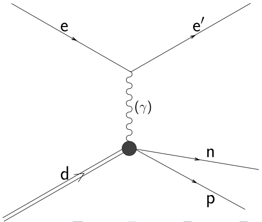
- How do the proton and neutron interact?

- Can this interaction be described using only nucleon degrees of freedom or do non-nucleon degrees of freedom also play a role?



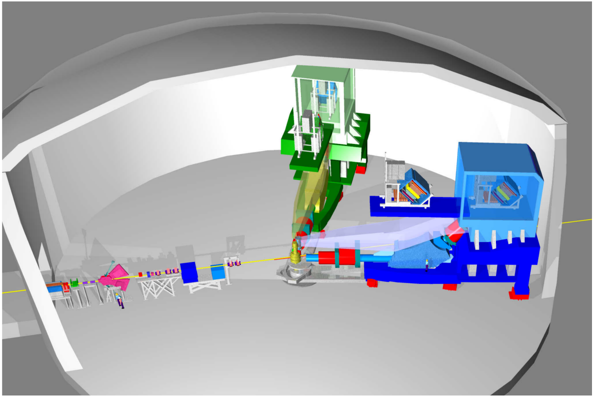
Why Electrodisintegration of Deuterium at Threshold?

- Why electrodisintegration?
  - It is a well-known probe.
  - “Simple”: Scattering dominated by exchange of single virtual photon.
  - Strong sensitivity to non-nucleon degrees of freedom.
- Why Deuterium?
  - Deuterium (^{2}H) is a simple, loosely bound 2-body object.
  - Provides way to study N-N interactions without having to consider 3-nucleon forces.
- The exclusivity of the reactions studied ($p(\vec{e}, e'p)$, $d(\vec{e}, e'p)n$) allow for access to the ratio G_{Ep}/G_{Mp} (for $x_B \epsilon$ [1,2]).
- Why at threshold?
  - At low Q^2 ($x_B \rightarrow 2$), the ratio G_{Ep}/G_{Mp} is sensitive to N-N interactions inside Deuterium.



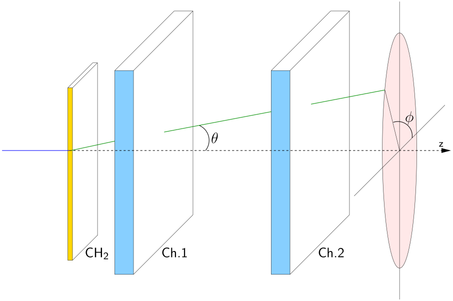
E08008: General Characteristics

- Ran from February 17^{th} to February 23^{rd}, 2011
- Took data on $p(\vec{e}, e'p)$, $d(\vec{e}, e'd)$ and $d(\vec{e}, e'p)n$ exclusive reactions.
- E_e = 3.358 GeV
- Q^2 acceptance: [0.71,0.90] $(GeV/c)^2$



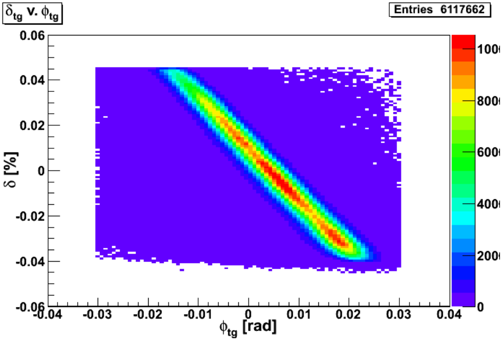
E08008: LHRS Detector Stack

- Detector stack slightly modified for E08008.
- Two FPPs used:
  - Four straw chambers, two analyzers.
  - CH_2 analyzing material placed in front of Chamber 1 and 2.
  - S2m used as second analyzer. Placed in front of Chamber 3 and 4.
- Spin-orbit interactions between recoil proton and analyzer material result in ϕ asymmetries $\Rightarrow$ reveals polarization of proton.



Preliminary Analysis of $p(\vec{e}, e'p)$

- E_{e^-} = 3.358 GeV
- Target: 4 cm LH_2
- LHRS
  - p = 0.968 GeV/c
  - $\theta = 57^\circ$
- RHRS
  - p = 2.95 GeV/c
  - $\theta = 16^\circ$

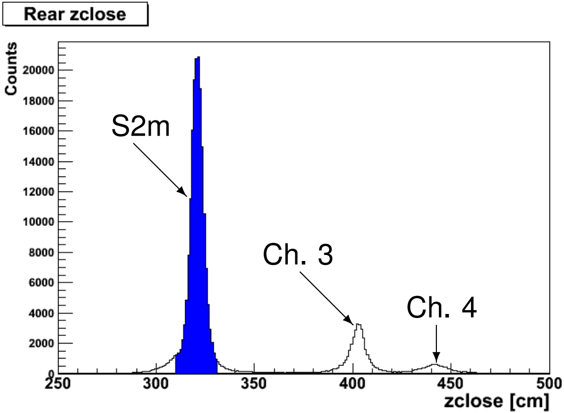


Applied Cuts:

- Kinematic cuts:
  - $|\delta| \leq 0.045$
  - $|\phi_{tg}| \leq 0.03$
  - $|\theta_{tg}| \leq 0.06$
  - -2 cm $\leq z_{vertex} \leq$ 2 cm
- FPP cuts:
  - "Conetest" (= 1)
  - $5^\circ < \theta_{fpp} < 30^\circ$
- Other cuts:
  - DBB.evtypebits (= 32) (T5 trigger)
  - 0.875 GeV $< W^2 <$ 0.92 GeV

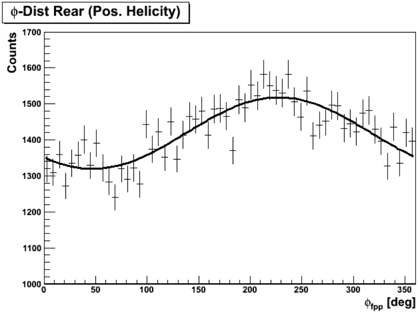
Preliminary Analysis of $p(\vec{e}, e'p)$

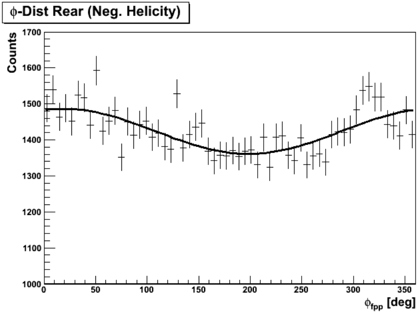
- One more cut on position of analyzing material (S2m)



Preliminary Analysis of $p(\vec{e}, e'p)$

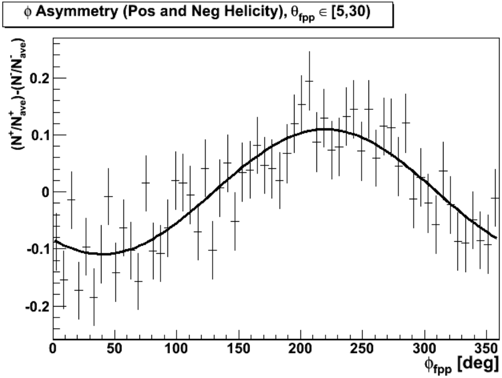
- Form ϕ-distributions (ϕ_{az}) for each helicity setting.





Preliminary Analysis of $p(\vec{e}, e'p)$: At the Focal Plane

- Form ϕ-distributions (ϕ_{az}) for each helicity setting.
- Form Helicity Asymmetry $\Rightarrow (\frac{N^+}{N^+_{ave}}) - (\frac{N^-}{N^-_{ave}})$
- Fit eqn: $y_0 + A_y[\ P_x^{fpp} cos(\phi) - P_y^{fpp} sin(\phi)\ ]$



Q^2 = [0.71, 0.84] $(GeV/c)^2$

y_0 = 2.894e-04 $\pm$ 0.004839

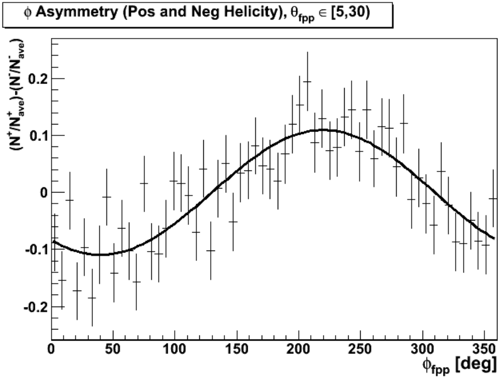
P_x^{fpp} = -0.2866 $\pm$ 0.0313

P_y^{fpp} = 0.2396 $\pm$ 0.0313

Preliminary Analysis of $p(\vec{e}, e'p)$: Phase Shift Method

- Fit eqn: $C \cdot cos(\phi + \delta)$; $tan(\delta) = \frac{P_y^{fpp}}{P_x^{fpp}}$
- In dipole approximation: $\mu_p \frac{G_{Ep}}{G_{Mp}} = \mu_p \cdot Ksin(\chi)(\frac{P_y^{fpp}}{P_x^{fpp}})$

  $K = \frac{E+E'}{m_p} tan^2(\theta_e/2)$; $\chi = \gamma(\mu_p - 1)\Theta_{bend}$



Q^2 = [0.71, 0.84] $(GeV/c)^2$

$\delta = -0.6962 \pm 0.0838$ rad

$$\mu_p \frac{G_{Ep}}{G_{Mp}} = 0.873801 \pm 0.149866$$

Preliminary Analysis of $p(\vec{e}, e'p)$: Phase Shift Method

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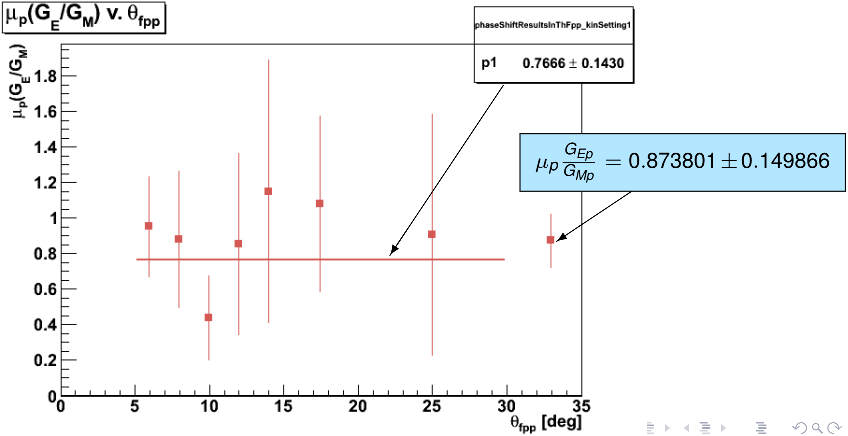

Preliminary Analysis of $p(\vec{e}, e' p)$: Sago

Palmetto

$\Longrightarrow$

Sago

Preliminary Analysis of $p(\vec{e}, e'p)$: Sago

- Palmetto (re)written for e08008 $\Rightarrow$ Sago.
- Uses information from FPP and a total rotation matrix (**S**).
- $\boldsymbol{P^{fpp}} = \boldsymbol{S} \cdot \boldsymbol{P^{tg}} = \boldsymbol{T_1 S_{sp} T_0} \cdot \boldsymbol{P^{tg}}$
  - $T_1 \rightarrow$ rotation into FPP frame
  - $S \rightarrow$ spin precession through HRS dipole
  - $T_0 \rightarrow$ rotation from target frame
- Briefly:

$$\begin{pmatrix} \Sigma_i \lambda_{x,i} \\ \Sigma_i \lambda_{z,i} \end{pmatrix} = \begin{pmatrix} \Sigma_i \lambda_{x,i}\lambda_{x,i} & \Sigma_i \lambda_{z,i}\lambda_{x,i} \\ \Sigma_i \lambda_{x,i}\lambda_{z,i} & \Sigma_i \lambda_{z,i}\lambda_{z,i} \end{pmatrix} \begin{pmatrix} P_x^{tg} \\ P_z^{tg} \end{pmatrix}$$

$$\boldsymbol{P^{fpp}} = \boldsymbol{S} \cdot \boldsymbol{P^{tg}}$$

- $\lambda_j = \eta h A_y (S_{yj} sin\phi - S_{xj} cos\phi)$
  - helicity (η), beam pol (h), analyzing power (A_y)
- Σ_i represents a summation over number of events, i
- Is solved for P_x^{tg} and P_z^{tg}

Preliminary Analysis of $p(\vec{e}, e'p)$: Sago

- Palmetto (re)written for e08008 ⇒ Sago.
- Uses information from FPP and a total rotation matrix (**S**).
- $P^{fpp} = S \cdot P^{tg} = T_1 S_{sp} T_0 \cdot P^{tg}$
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$$P^{fpp} = S \cdot P^{tg}$$

- $\lambda_j = \eta h A$
  - helicity
  - beam p
- Σ_i repres
  of events
- Is solved

After solving for P_x^{tg} and P_z^{tg} :

$$\mu_p \frac{G_{Ep}}{G_{Mp}} = K \frac{P_x^{tg}}{P_z^{tg}}$$

where:

$$K = -\mu_p \frac{E_e + E_{e'}}{2M_p} tan \frac{\theta_e}{2}$$

Preliminary Analysis of $p(\vec{e}, e'p)$: Sago

- Palmetto (re)written for e08008 $\Rightarrow$ Sago.
- Uses information from FPP and a total rotation matrix (**S**).
- $\boldsymbol{P^{fpp} = S \cdot P^{tg} = T_1 S_{sp} T_0 \cdot P^{tg}}$
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Sago Results: $\mu_p \frac{G_{Ep}}{G_{Mp}} = 0.928243 \pm 0.155129$

- beam p
- Σ_i repres of events
- Is solved

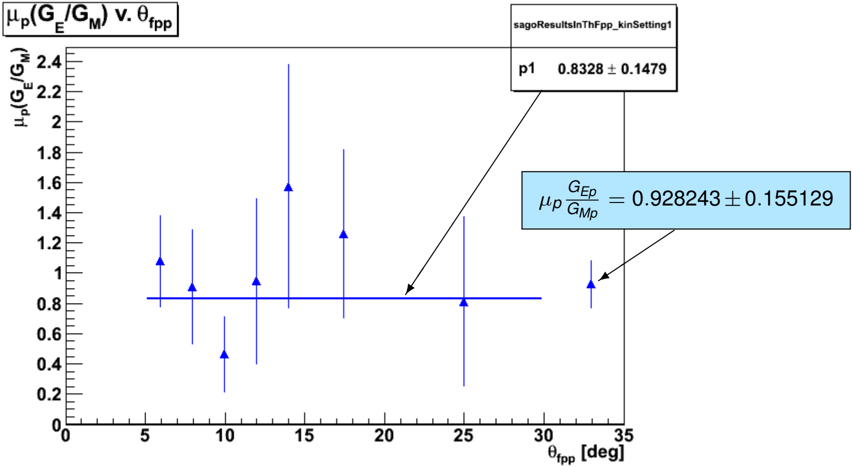
$$\mu_p \frac{G_{Ep}}{G_{Mp}} = K \frac{P_x^{tg}}{P_z^{tg}}$$

where:

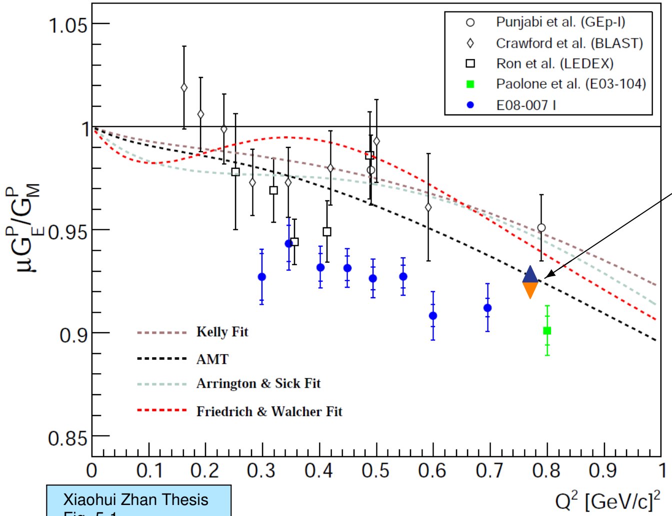
$$K = -\mu_p \frac{E_e + E_{e'}}{2M_p} tan \frac{\theta_e}{2}$$

Preliminary Analysis of $p(\vec{e}, e'p)$: Results using Sago

- Sago results binned in θ_{fpp}:



Preliminary Analysis of $p(\vec{e}, e'p)$: Results using Sago

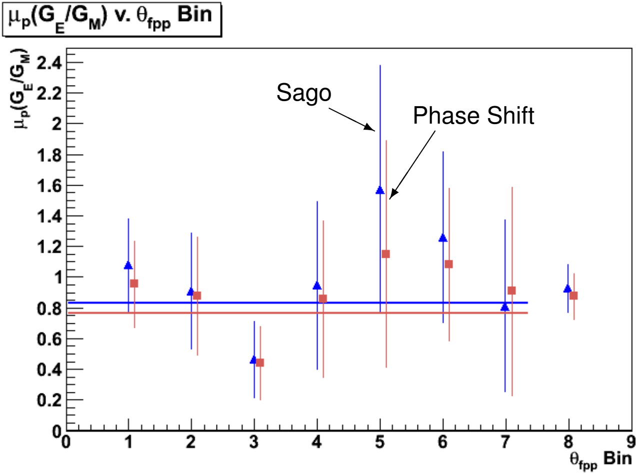


Preliminary Result (for $p(\vec{e}, e'p)$)

Xiaohui Zhan Thesis
Fig. 5-1

Preliminary Analysis of $p(\vec{e}, e'p)$: Comparison of Methods

- Comparison between Phase Shift Method and Sago:



Preliminary Analysis of $d(\vec{e}, e'p)n$

- Extraction of $\mu_p \frac{G_{Ep}}{G_{Mp}}$ follows very similar procedure.

Method	$p(\vec{e}, e'p)$	$d(\vec{e}, e'p)n$
Phase Shift	0.873801 ± 0.149866	0.892813 ± 0.092599
Sago	0.928243 ± 0.155129	0.912247 ± 0.108031

Summary

- While cross section measurements are needed to disentangle G_{Ep} and G_{Mp}, the **ratio** of the two can be “readily” extracted using double-spin asymmetries.
- At low Q^2 ($x_B \to 2$), the ratio G_{Ep}/G_{Mp} is sensitive to N-N interactions inside Deuterium.
- Preliminary Measurements of $\mu_p(G_{Ep}/G_{Mp})$:
  - $p(\vec{e}, e' p) \Rightarrow$ agrees with previous results
  - $d(\vec{e}, e' p)n$ (quasi-elastic) $\Rightarrow$ agrees with expected value
- Still to do:
  - Study measurements for $d(\vec{e}, e' p)n$ reactions where $x_B = 1$.
  - Continue measurements for lower momentum settings where $x_B \to 2$.