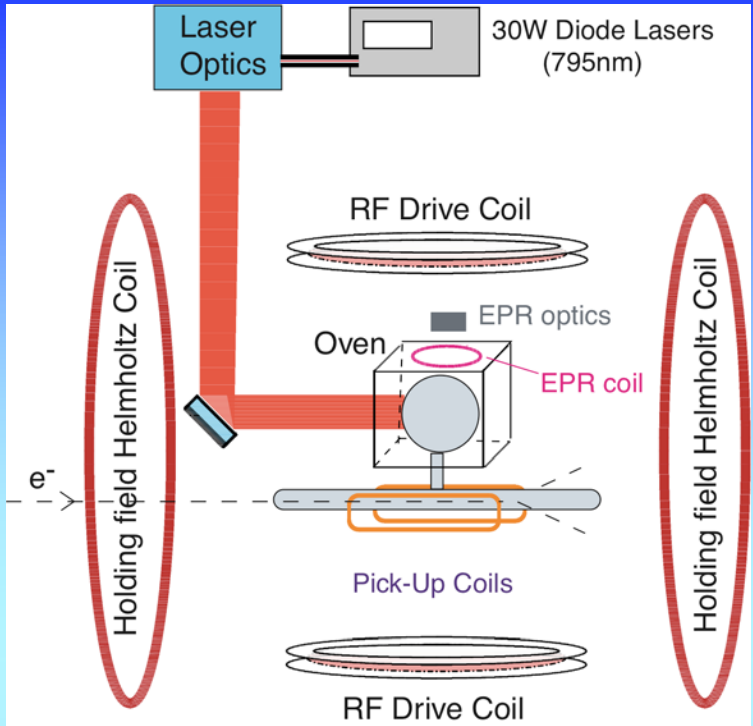
Hall A
Collaboration Meeting
12-14 June 2008

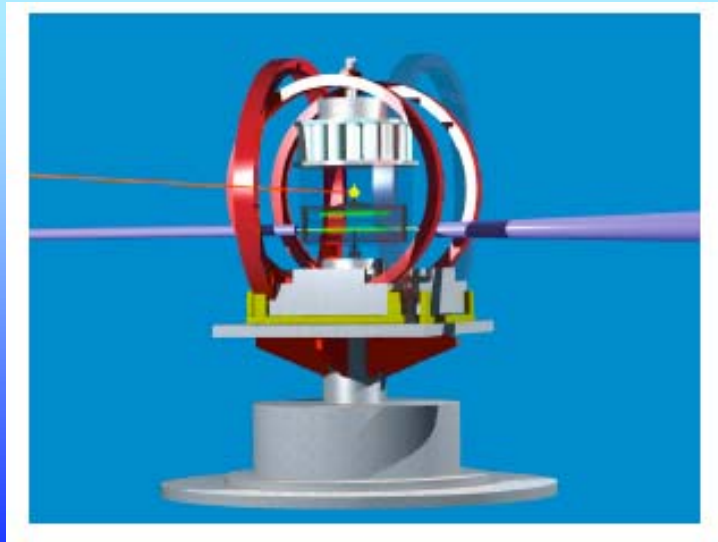
DVCS with a High Luminosity Polarized ^3He Target

Charles Hyde[1,2], Gagik Gavalian[2]
[1]Université Blaise Pascal
[2]Old Dominion University

Hall A Polarized ^3He Target

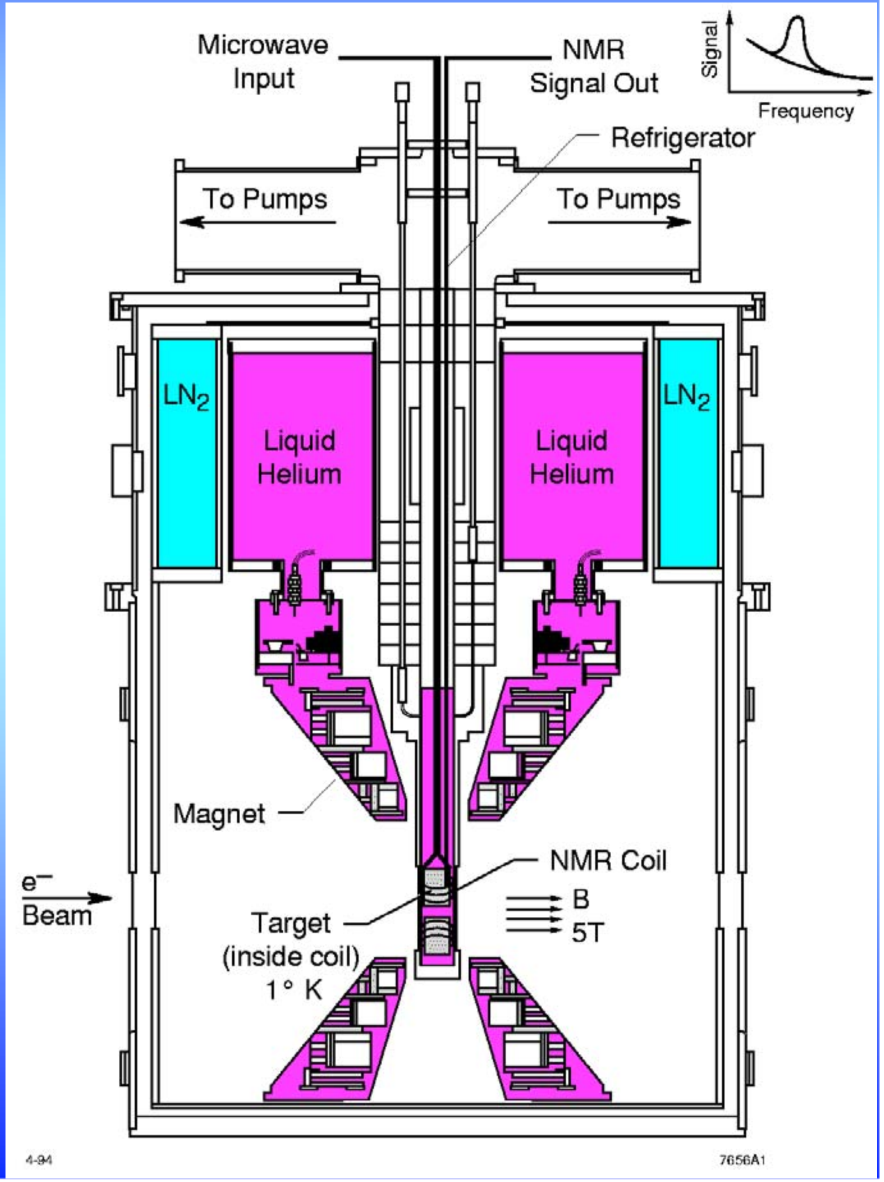
- Maximum neutron luminosity 10^{36}
  - 14 atm × 40 cm
- "Background" Luminosity
  - Protons in ^3He + entrance and exit windows
  - $10^{37}/cm^2/s$ total luminosity
- Polarization 50%
  - Nuclear Physics dilution factor 0.86 (d-state)
  - -2.8% proton polarization
  - Longitudinal and Transverse (relative to **q**)
- Large secondary background
  - BigBite suggests equivalent to $3 \cdot 10^{37}/cm^2/s$





Hall B/C Polarized Proton/Deuterium

- Polarized NH_3, ND_3
- Total Luminosity ≲10^{35}
- Polarization
  - Proton ≲80%
  - Deuteron ≲30%
  - Dilution factor ≈ 1/10
- Longitudinal polarization:
  - 45° downstream acceptance
- Transverse polarization
  - Limited acceptance, or
  - New magnet required
- HD target
  - Luminosity • Pol² • Acceptance unknown for electrons



Hall A Figure of Merit

- Typical bins (Hall A or CLAS)
  - $[\Delta Q^2, \Delta x_B]=[1.0\ GeV^2, 0.1]$
- For *t*-range of DVCS calorimeter
  - HRS vertical angle acceptance $\Delta\theta_V = \pm 60$ mr
  - Azimuthal acceptance $(\Delta\phi_e/2\pi) = 120mr/\sin\theta_e \approx 1/20$
- Figure of merit ^3He target
  - $(\text{Luminosity})(\text{acceptance})(\text{Polarization})^2$
  - $FOM = (10^{36})(1/20)(0.5*0.86)^2 \approx 10^{34}$

CLAS12 NH_3 Figure of Merit

- Proton
  - Luminosity 10^{35}
  - Polarization (proton) 80%
  - $(e,e'\gamma)$ Acceptance ≤50%
  - Dilution 0.1
- FOM(proton) = $(10^{35})(1/20)(0.8)^2 \approx 3\cdot10^{33}$
- FOM(neutron)= $(10^{35})(1/20)(0.3)^2 \approx 5\cdot10^{32}$
- Transversely Polarized target
  - $e^+e^-\gamma$ "Sheet-of-flame" in plane perpendicular to B-field of target.
  - Luminosity times acceptance x1/10

Target Comparison

- Hall A ^{3}He target neutron FOM is a factor of 3 better than CLAS12 proton FOM
  - Improve the He3 Luminosity?
  - Decrease the background luminosity from glass walls?
  - CLAS12 measures larger t-range, all bins in (Q2,xB)
- Hall A neutron FOM is a factor of 20 better than CLAS12 neutron FOM from ND3
- HD target in Hall B may offer better product of Luminosity•Polarization^2• acceptance than NH3.
  - FOM for transversely polarized HD likely still less than FOM for longitudinal NH_3.

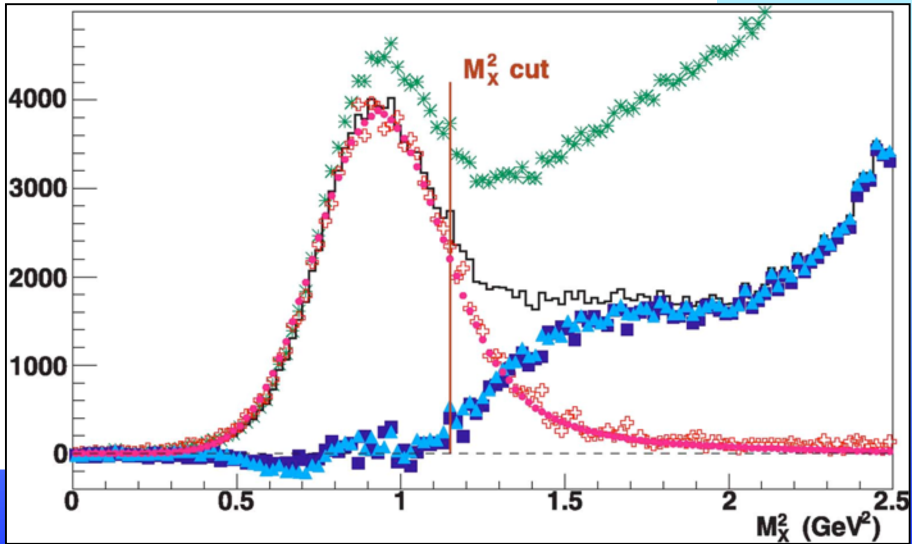
^{3}He Target Upgrade Conjecture

- Separate Polarization and Target Volumes
  - Increase polarization throughput by factor of 10 to 100.
  - Cool and/or compress ^{3}He in target area by factor of 10
    - 10K at 10 atm x 20 cm
  - Rapid cycling of ^{3}He through target
    - Reduce depolarization effect of target density, beam current, target walls
    - Replace thick glass with thin metallic walls.
- Neutron luminosity 10^{37}
  - Proton luminosity $2 \cdot 10^{37}$
  - Endcaps $\leq 10^{37}$
- Target Polarization = $0.5 \cdot (0.86n - 0.028p)$

Neutron DVCS in ^{3}He Target

$$\vec{n}(\vec{e},e'\gamma)n \text{ via } {}^3\vec{H}e(\vec{e},e)X$$

- Target spin-dependent cross sections
  - 0.86"neutron"-0.028"proton" from 3He wave-function
- Fermi-motion of neutron in ^{3}He
  - Smearing of QF neutron contribution with pion-production channels $N(e,e'\gamma)N\pi$
  - $H(e,e'\gamma)X$: M_X^2 resolution $\sigma(M_X^2) \approx 0.22$ GeV^2.
  - For $-t<0.4$ GeV^2 and $p_N<250$ MeV/c, QF smearing contributes ≤ 0.1 GeV^2 to $\sigma(M_X^2)$.



Neutron DVCS Observables (Long.Pol.)

$d\sigma(\lambda,\Lambda)$ for $\vec{n}(\vec{e},e'\gamma)n$ via $^3\vec{H}e(\vec{e},e)X$

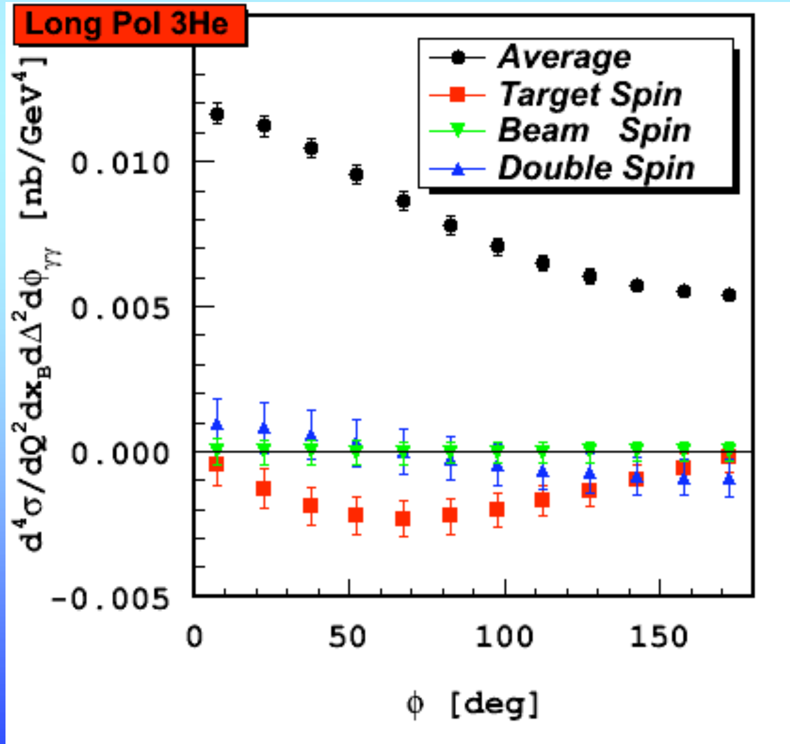
λ, Λ = electron, ^{3}He Polarization

- Long or Transverse Normal Polarization
- Target Single Spin Cross Sections
  - $d\sigma_{LSS} = \Sigma_{\lambda\Lambda} \Lambda d\sigma(\lambda,\Lambda)/4 \sim \sin\phi_{\gamma\gamma}$
    Im[BH*DVCS] (Twist-2)
    Unpolarized Protons in 3He cancel
- Target Double Spin
  - $d\sigma_{LDS} = \Sigma_{\lambda\Lambda} \Lambda\lambda d\sigma(\lambda,\Lambda)/4 \sim c_0 + c_1\cos\phi_{\gamma\gamma}$
    $\mathrm{Re}[BH^2 + (BH^*DVCS) + DVCS^2]$
    Unpolarized protons cancel
- Transverse Sideways: $\sin\phi_{\gamma\gamma} \Leftrightarrow \cos\phi_{\gamma\gamma}$
- All other "neutron" observables ($d\sigma$, Beam-spin) have large incoherent proton contributions

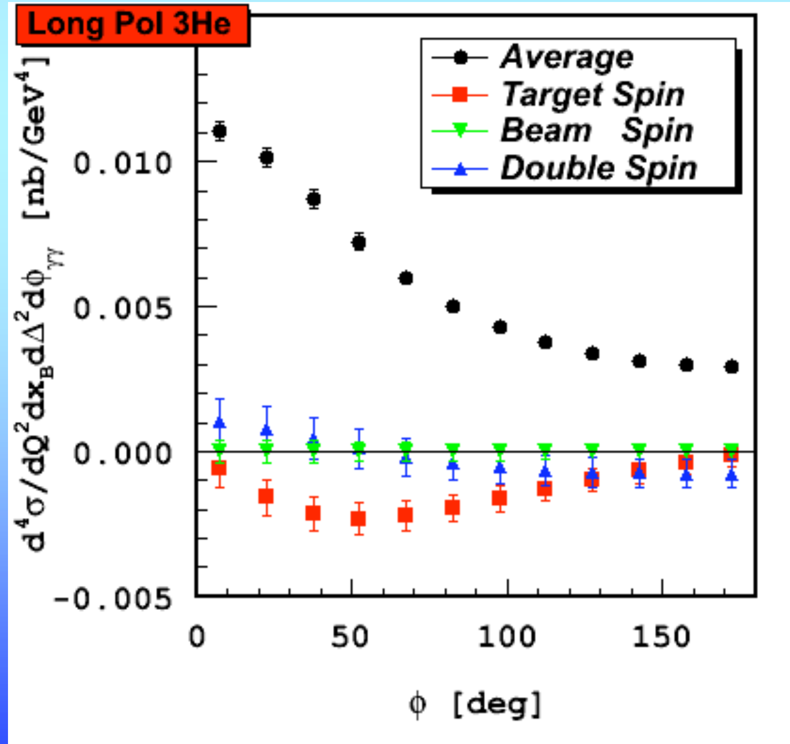
Longitudinally Polarized "Neutron"

- k=8.8 GeV, Q^2=4.0 GeV^2, x_{Bj}=0.36
  - VGG (Ju,Jd) = (0.3, 0.2): H, E, H-tilde
  - 20 days at 10^{37}/cm^2/s (50%x80% Polarization)

$t_{min}-t$ = 0.05 GeV^2

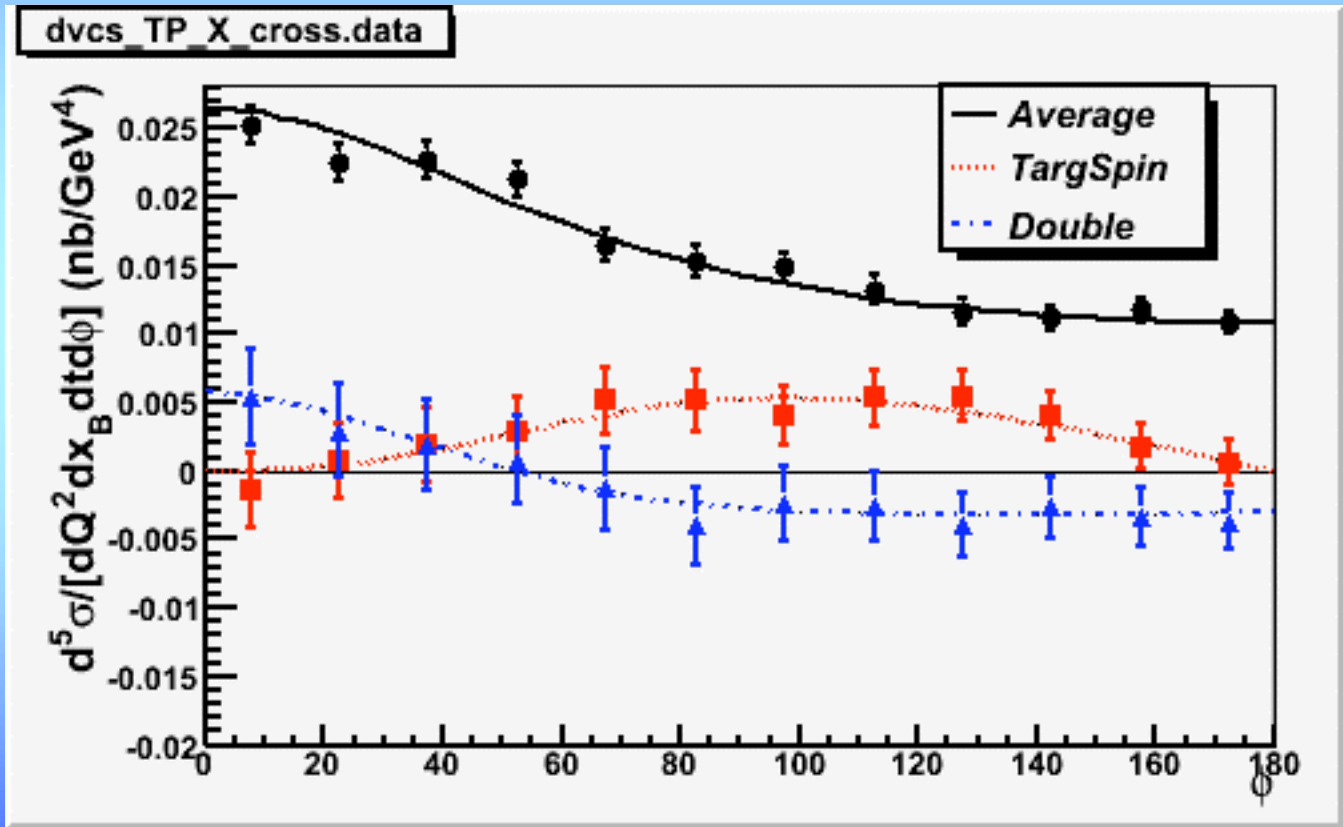


$t_{min}-t$ = 0.15 GeV^2



Transversely Polarized Neutron
Sideways =|| to (e,e') scattering plane

- 'VGG': Q^2=2.3 GeV^2, x_{Bj}=0.36, t = -0.26 GeV^2.

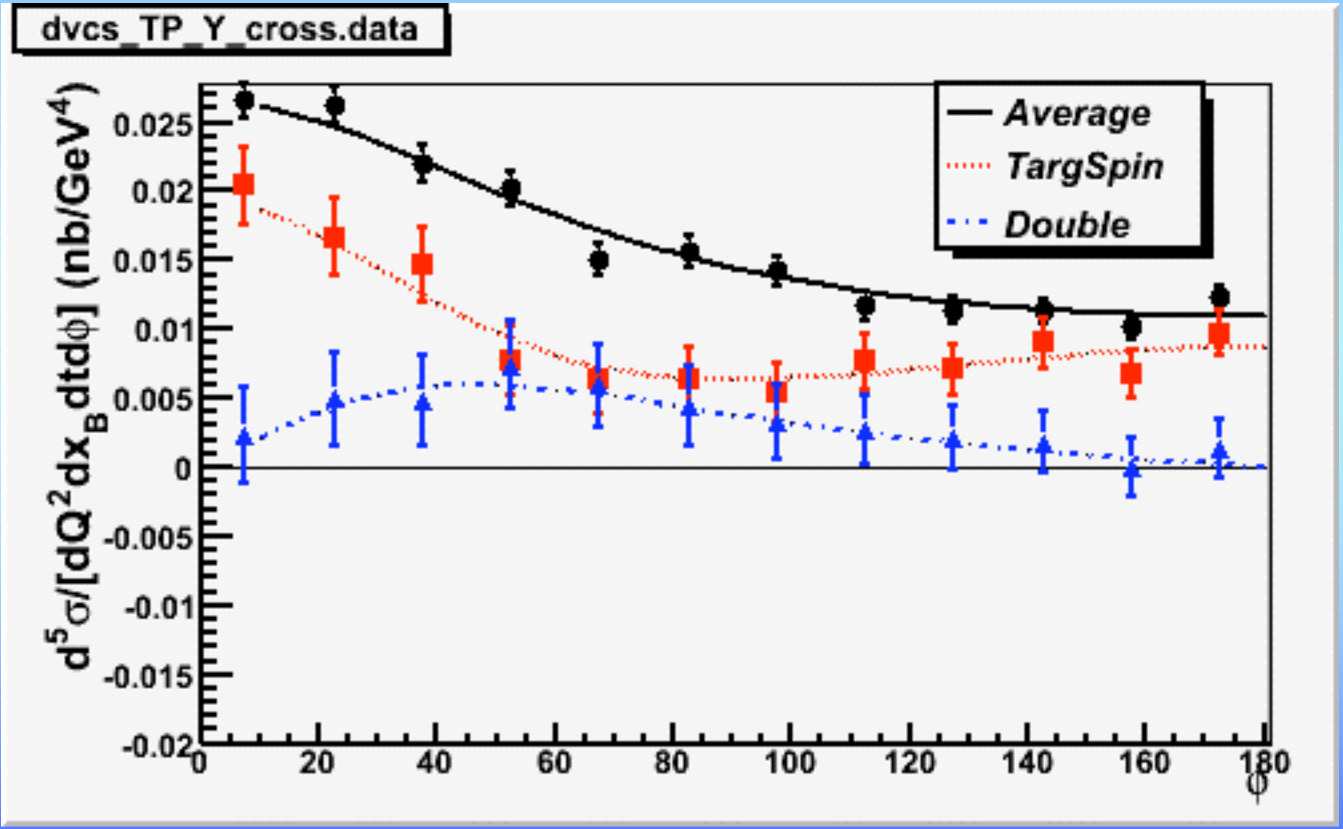


10 days at 10^{37}

(Ju,Jd) = (0.3,0.2)

Transverse Polarized Neutron
Normal = ⊥ to (e,e′) scattering plane

- 'VGG': Q^2=2.3 GeV^2, x_{Bj}=0.36, t = -0.26 GeV^2.



10 days at 10^{37}

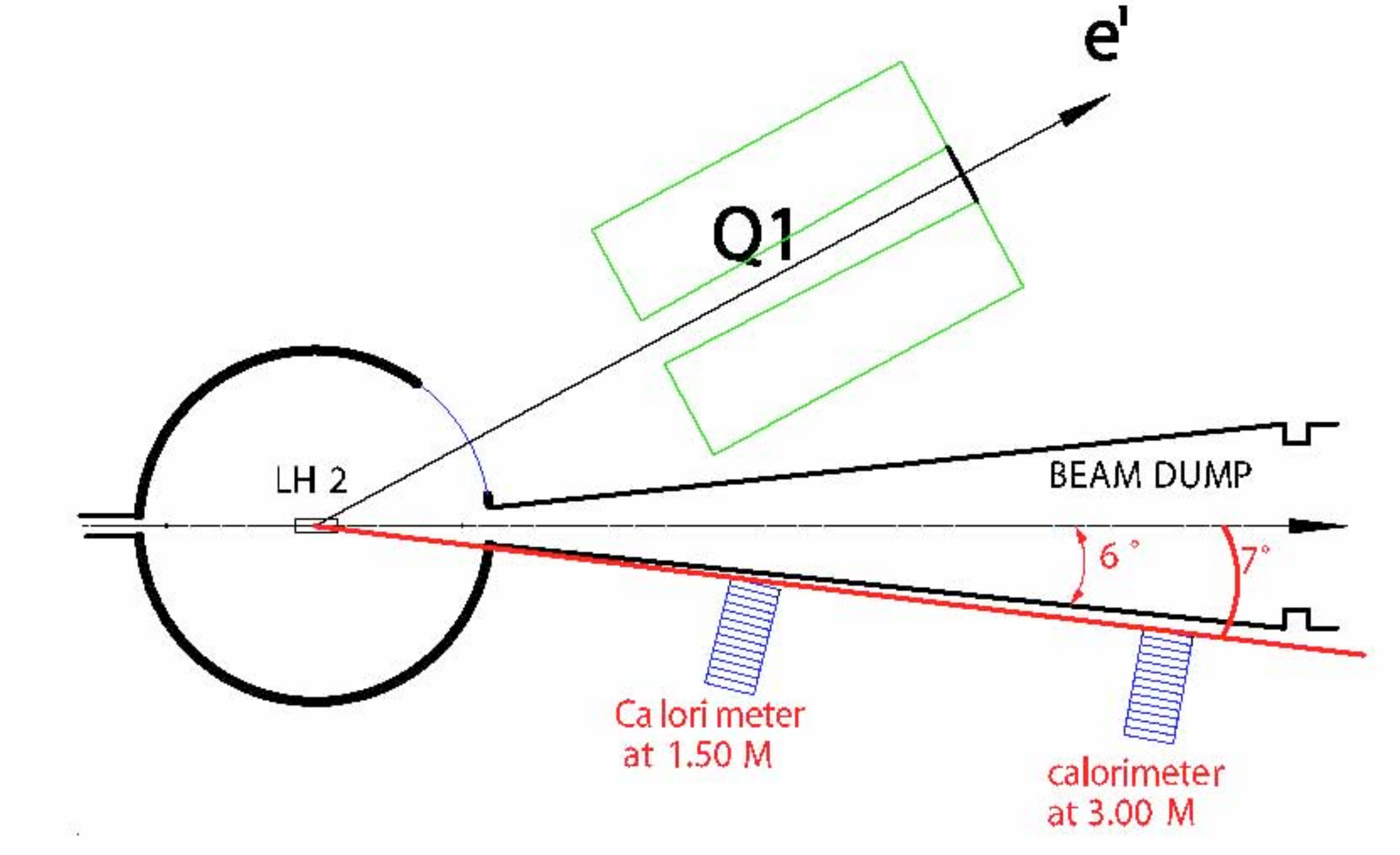
(Ju,Jd) = (0.3,0.2)

Conclusions

- L,T spin observables have different sensitivity to H, E, etc.
- Form factor weights in [*BH*DVCS*] terms give different sensitivity to *H, E,* etc in proton, neutron targets.
- [0*.86n-0.03p*] is a linearly independent flavor combination relative to p
- Extensive polarized neutron program for 12 GeV DVCS possible with a high luminosity ^{3}He target.
- New DVCS cross section & observables code from G. Gavalian

12 GeV DVCS Beamline

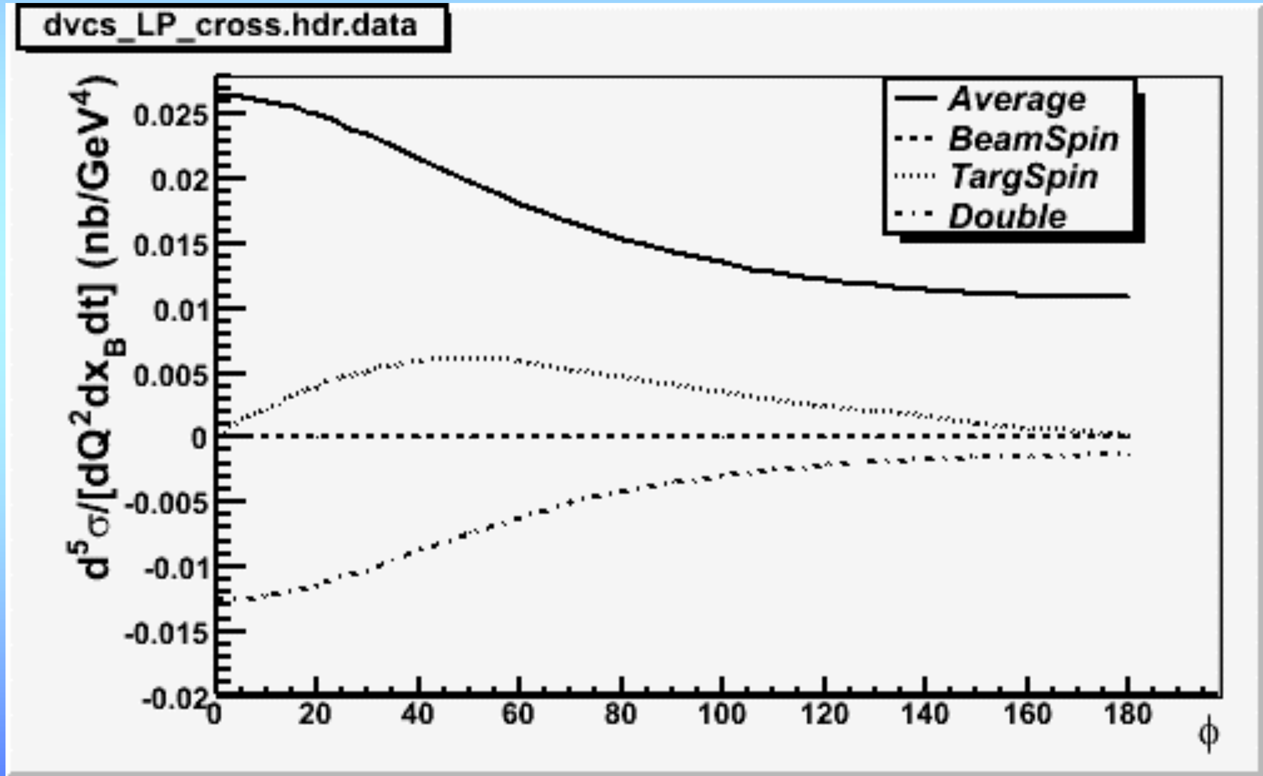
Calorimeter at small angle prefers short target



Longitudinally Polarized Neutron

- 'VGG': Q^2=2.3 GeV^2, x_{Bj}=0.36, t = -0.26 GeV^2.

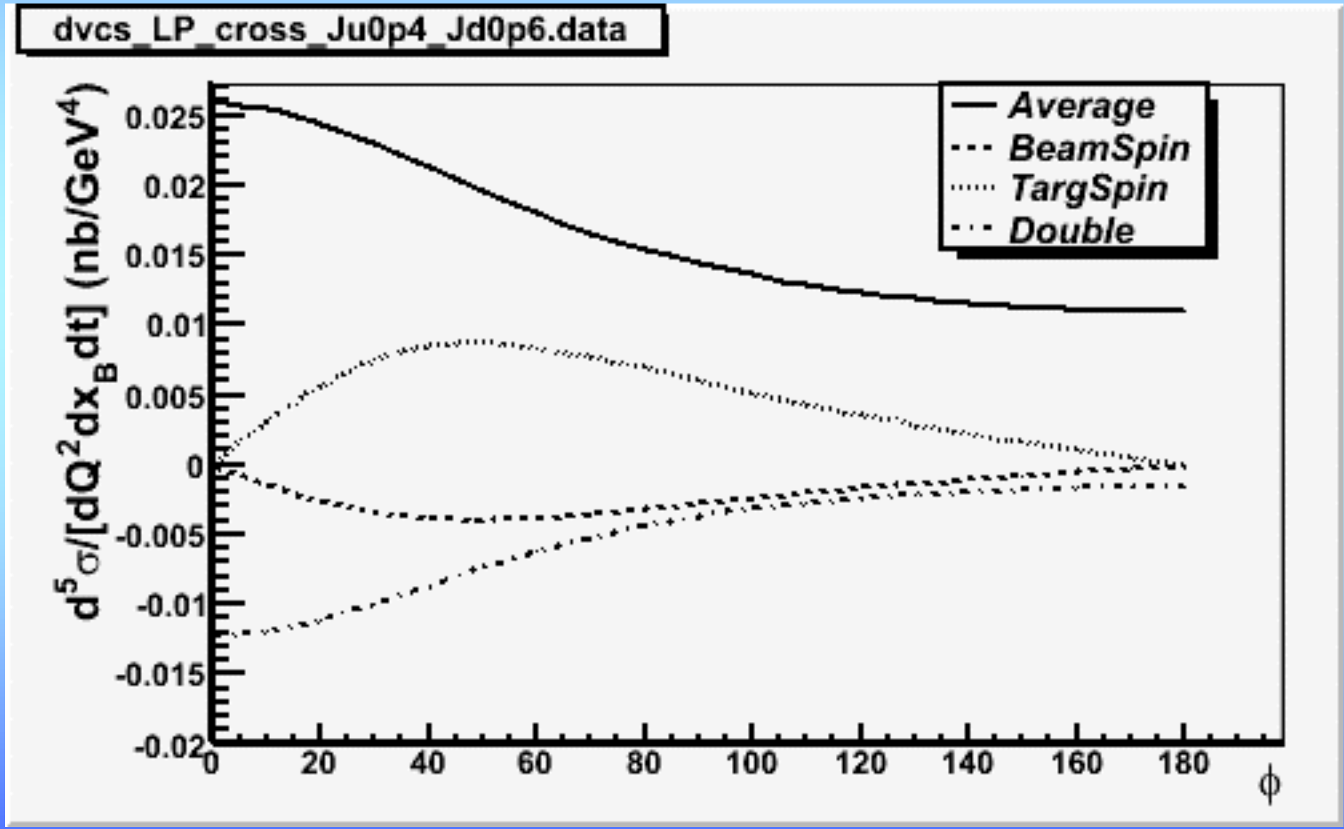
$$\frac{d^5\sigma}{dQ^2 dx_{Bj} dt d\phi d\varphi}$$



BSA≈0 for (Ju,Jd) = (0.3,0.2)

Longitudinally Polarized Neutron

- 'VGG': Q^2=2.3 GeV^2, x_{Bj}=0.36, t = -0.26 GeV^2.



BSA≠0 for (Ju,Jd) = (0.4,0.6)