Measurements of Target Single-Spin Asymmetries in QE $^3He^{\uparrow}(e, e')$

Update of QE A_y (E05-015) experiment

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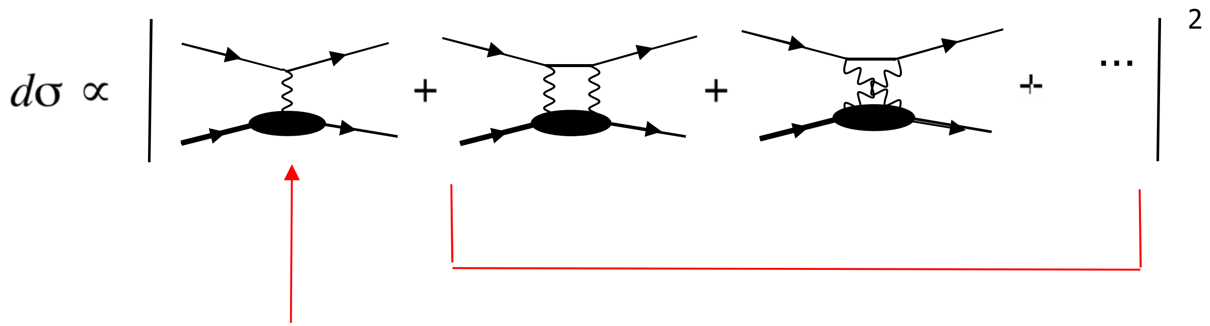
Outline

- Physics motivation.
- Existing world data.
- Experiment setup and kinematics.
- Target performance during experiment.
- Preliminary results.
- Summary and future plan.

Physics Motivation

e-N scattering:



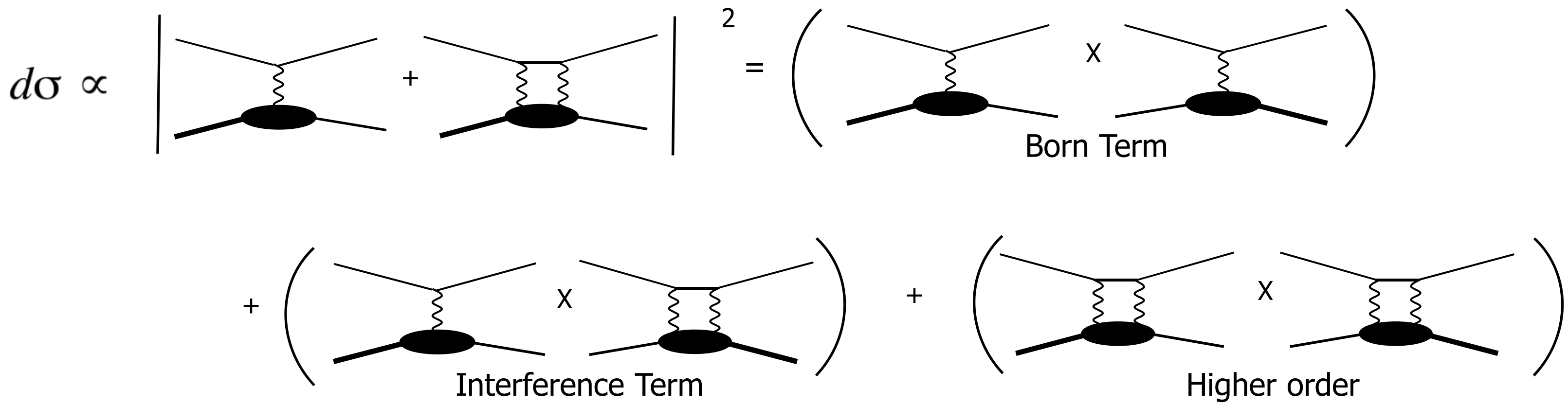
Leading contributor

Higher order terms

2γ physics: Study the contribution of higher order terms

Physics Motivation

How do we know that an asymmetry is due to 2γ physics?



transition amplitude: $T = T_{1\gamma} + T_{2\gamma}$

$$A_y \propto \frac{\mathrm{Im}\left(T_{1\gamma} T_{2\gamma}^{*}\right)}{|T|^2}$$

A. DeRujula *et al., Nuc. Phys. B35* (1971) 365

Born Approximation:

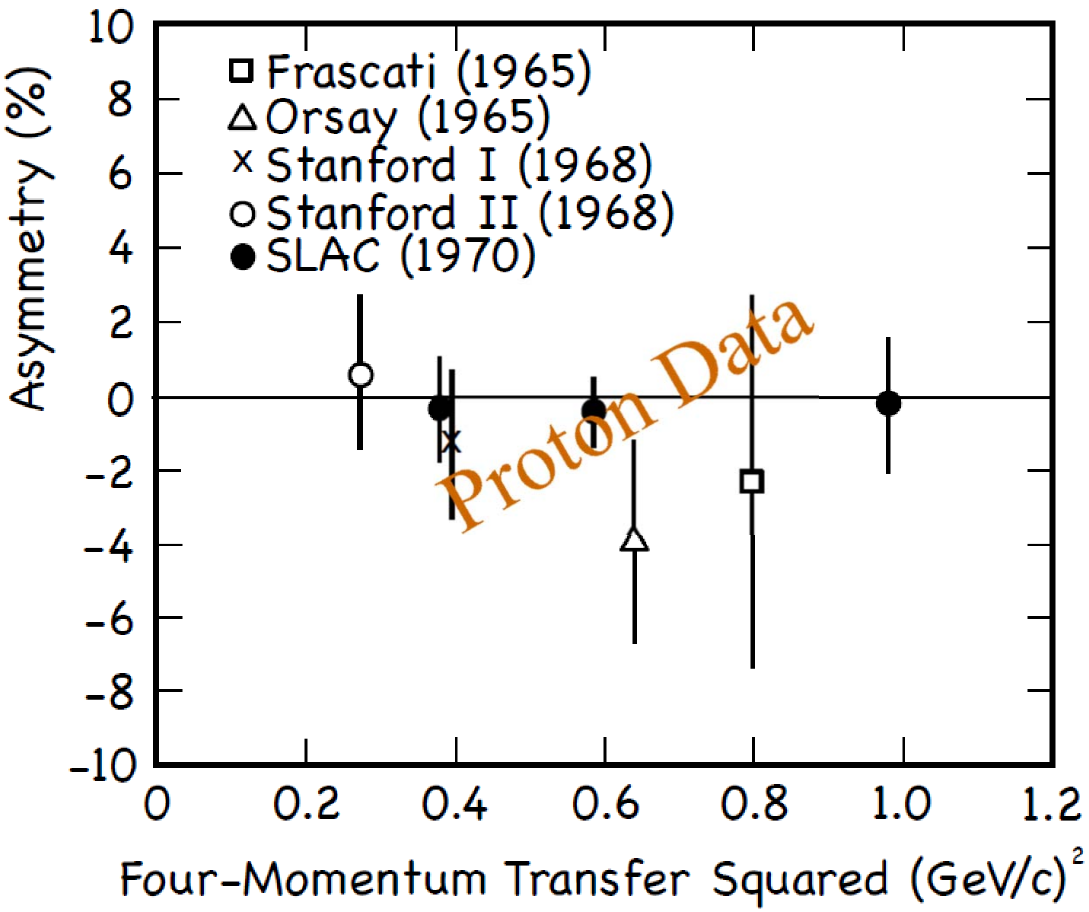
$T_{2\gamma} = 0$ $T_{1\gamma} =$ Real ➡ $A_y = 0$

N. Christ and T.D. Lee, Phys. Rev. 143, 1310 (1966)

Include 2γ exchange:

$T_{2\gamma}$ has an imaginary part ➡ $A_y \neq 0$

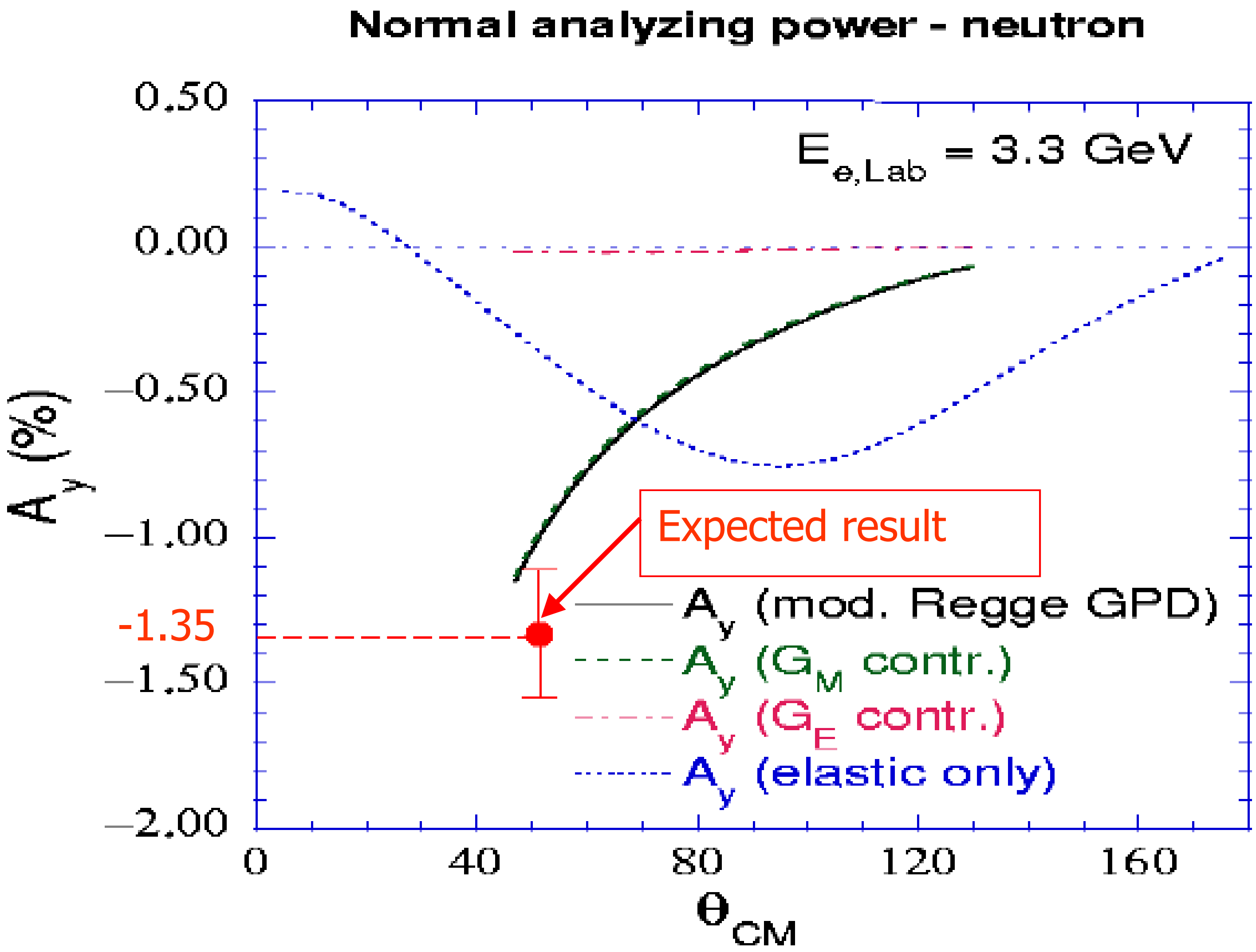
Existing World Data



- A high-enough precision measurement does not exist!

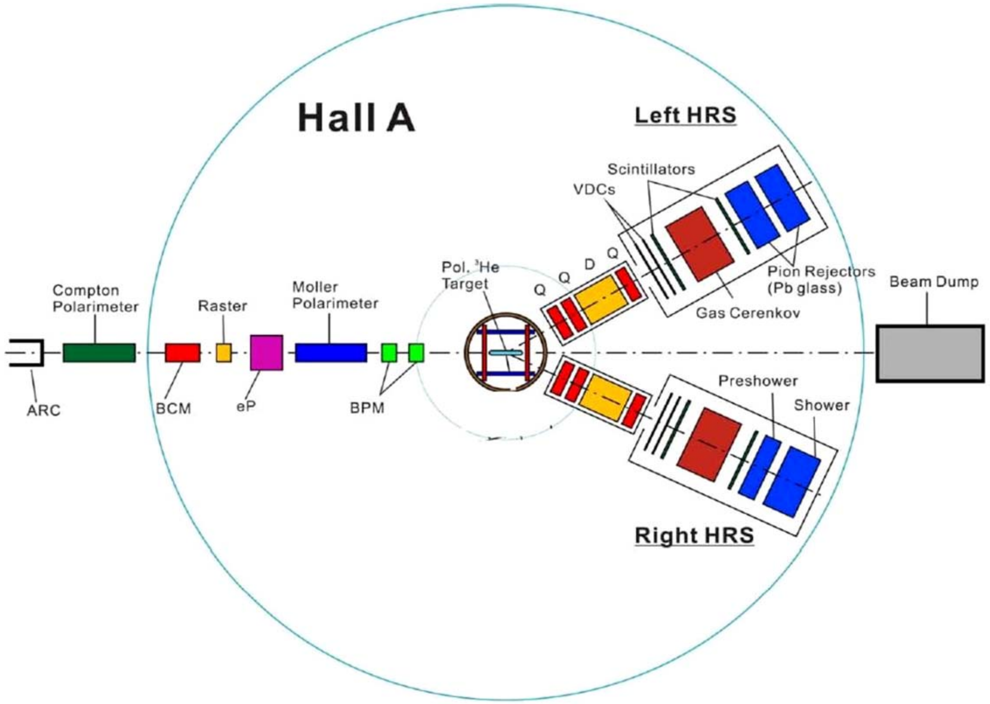
- Make a precise non-zero measurement of Ay.
- Provide quantitative information about the imaginary part of the two-photon exchange process.
- 2-photon-exchange process provides a new way to study nucleon structure, in this case, an integral of GPDs.

Theoretical Prediction



Experiment Setup & Kinematics

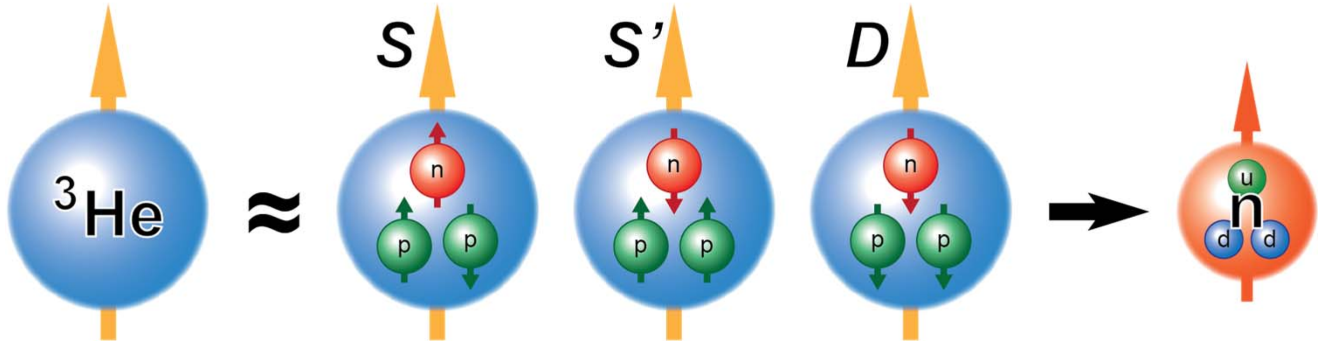
QE A_y experiment (E05-015) was run from April 26th to May 12th in 2009 at Jefferson Lab Hall A



$$A_y = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}} = \frac{N_e^{\uparrow} - N_e^{\downarrow}}{N_e^{\uparrow} + N_e^{\downarrow}}$$

E_0 [GeV]	E' [GeV]	θ_{lab} [Deg]	Q^2 [GeV]^2	$\|q\|$ [GeV]
1.25	1.22	17	0.13	0.359
2.43	2.18	17	0.46	0.681
3.61	3.09	17	0.96	0.988

Polarized ^3He Target



86%   1.5%   12%

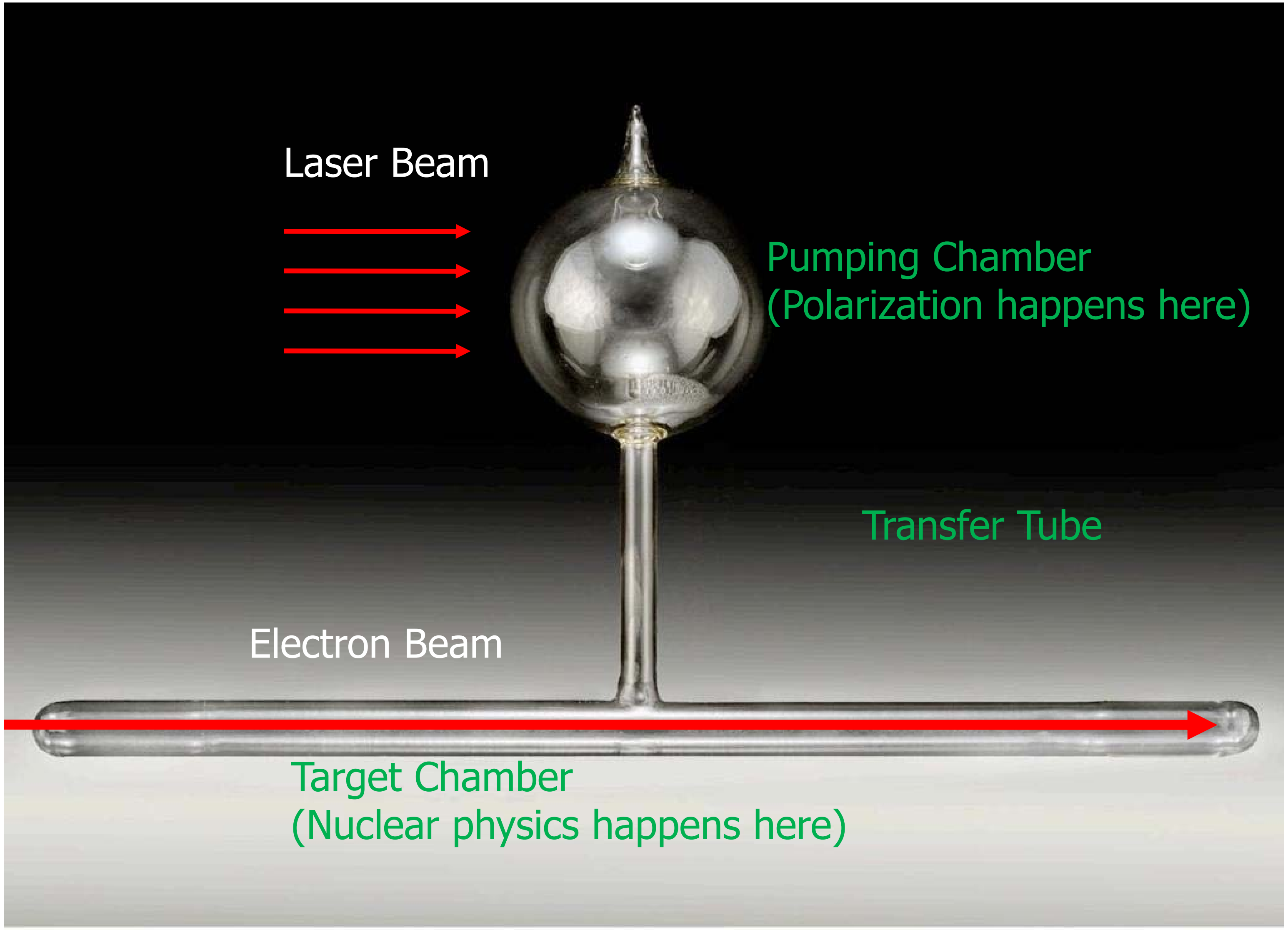
F. R. P. Bissey, A. W. Thomas, and I. R. Afnan, Phys. Rev. C64, 024004 (2001)

Why ^3He?

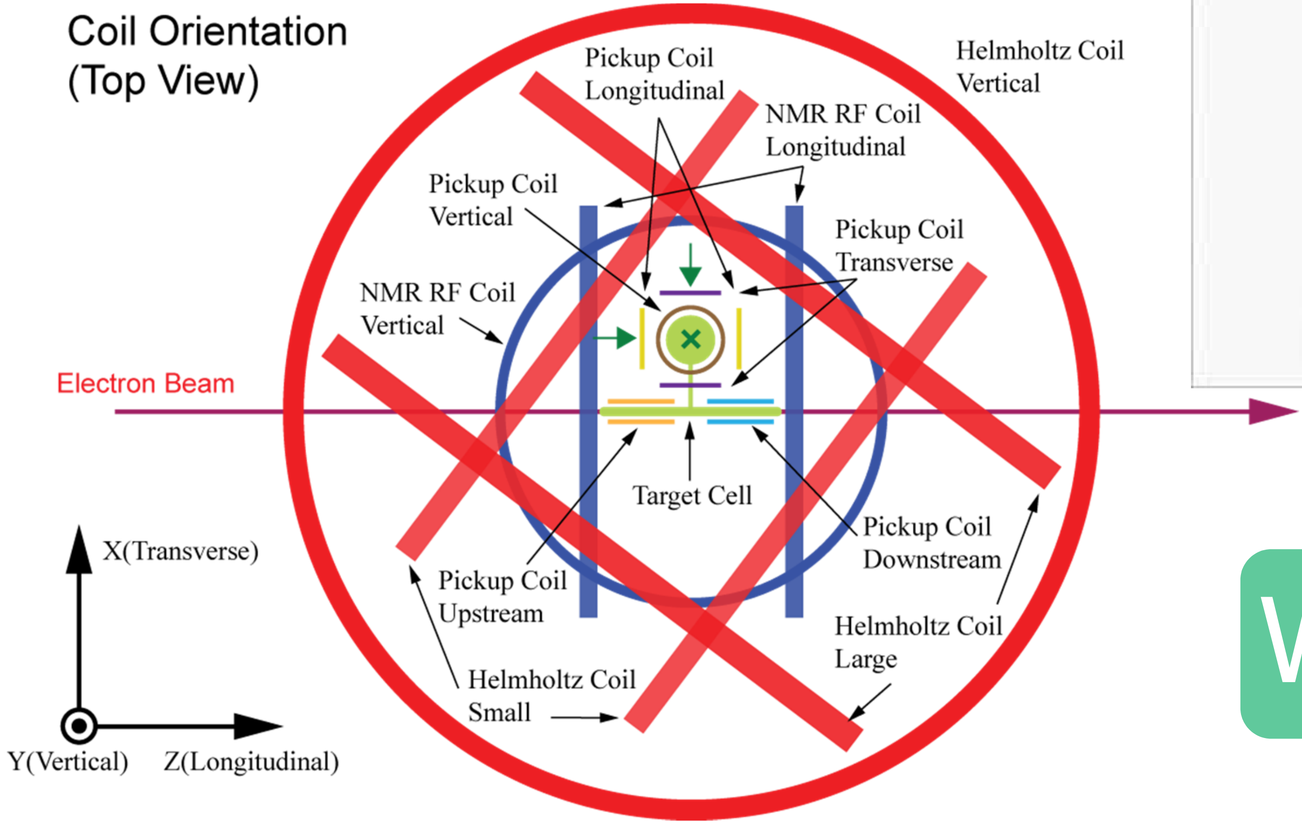
No free neutrons – they decay in less than 15 minutes!

^3He and Deuteron are two good candidates for a neutron target.
In ^3He the protons are nearly unpolarized, but in the Deuteron the proton and neutron are equally polarized.

Polarized ^3He Target

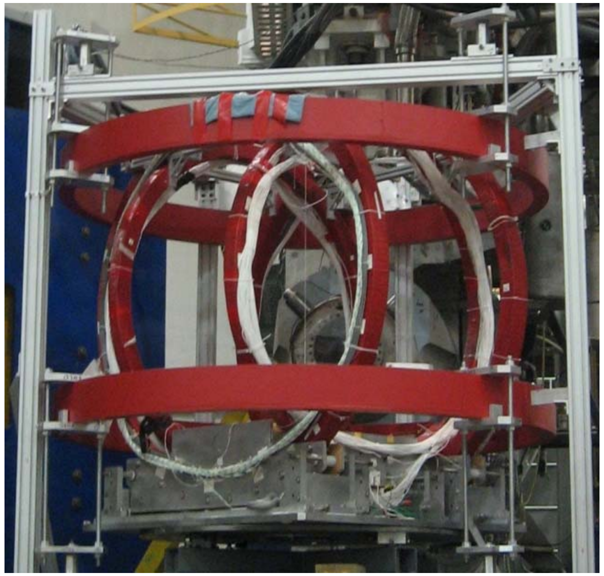


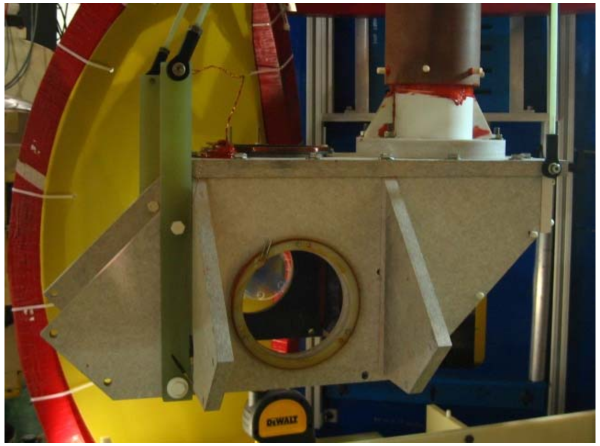
Magnetic Field



Wow, 3D!

Hall A Polarized ^{3}He Target





New lasers

Narrow line lasers make more efficient optical pumping.

3D Holding Field Control

New vertical coil together with existing horizontal coils create holding field in any direction.

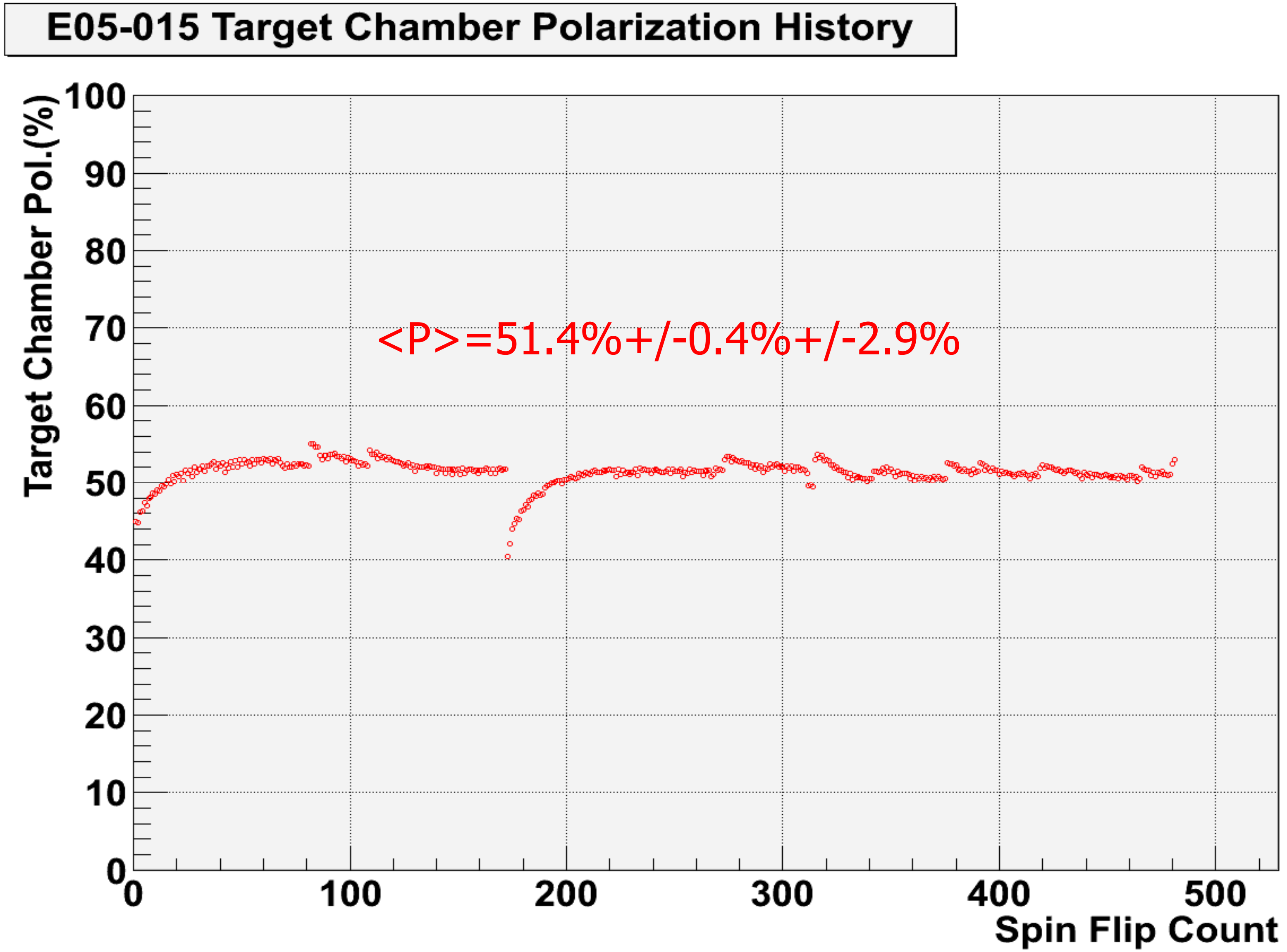
New Oven and Optics

Better insulation, lighter weight and all three pumping directions.

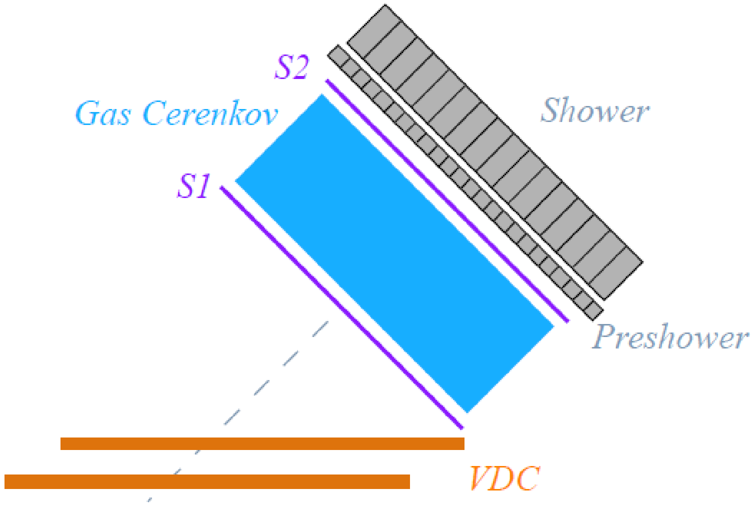
A Smart Target

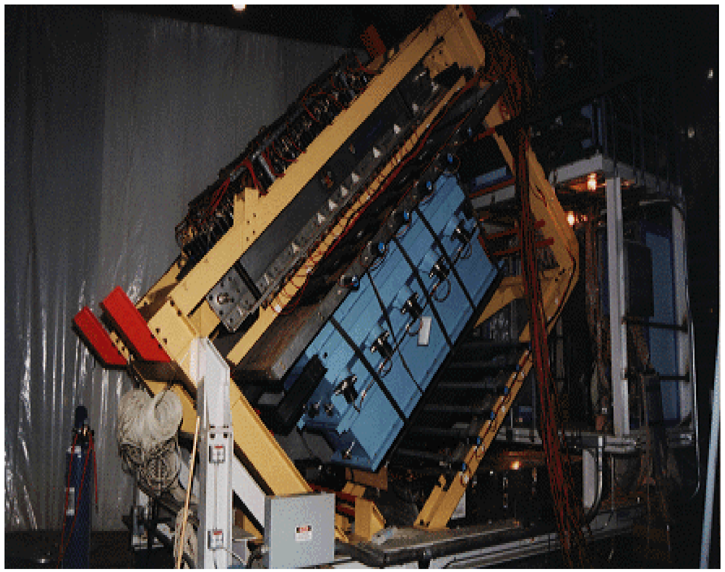
Automatic spin flip every 20 minutes using Adiabatic Fast Passage (AFP). Log and alarm.

Target Performance During Ay



Detector Package





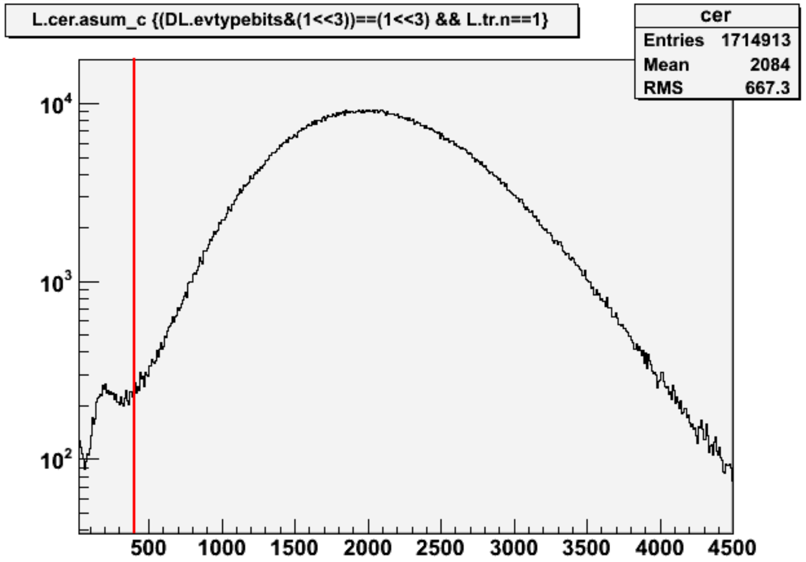
1). A pair of Vertical Drift Chambers (VDCs) determine the trajectory of particles;

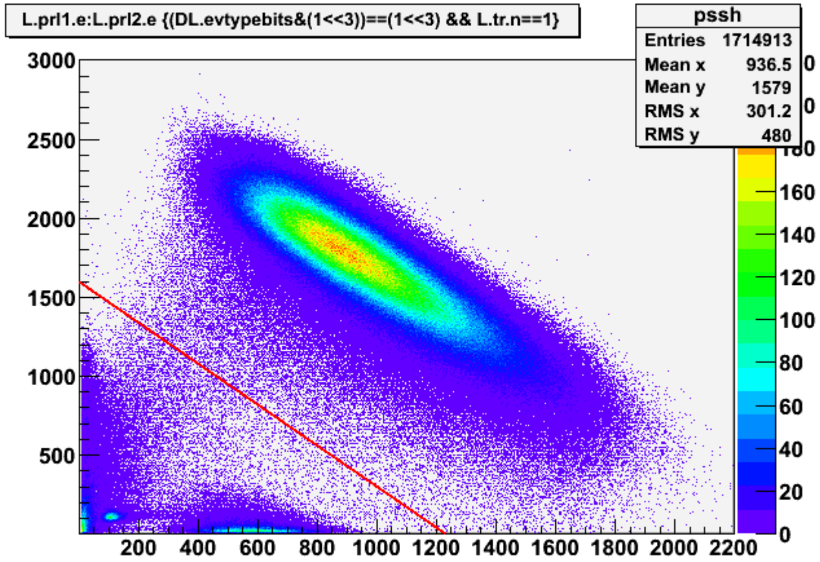
2). Two scintillator planes (S1 and S2) generate the trigger and the time-of-flight information;

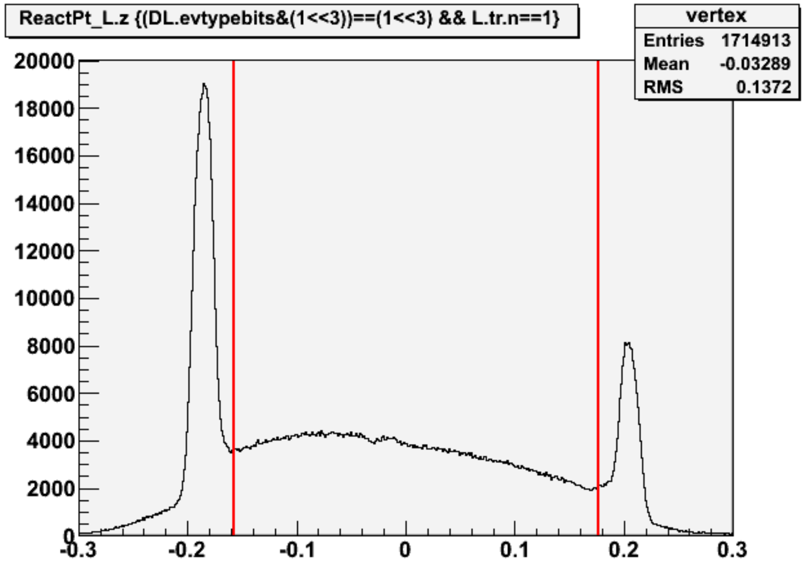
3). A Gas Cerenkov detector separates e^-/π^-;

4). A preshower and a shower counter give additional e^-/π^- separation.

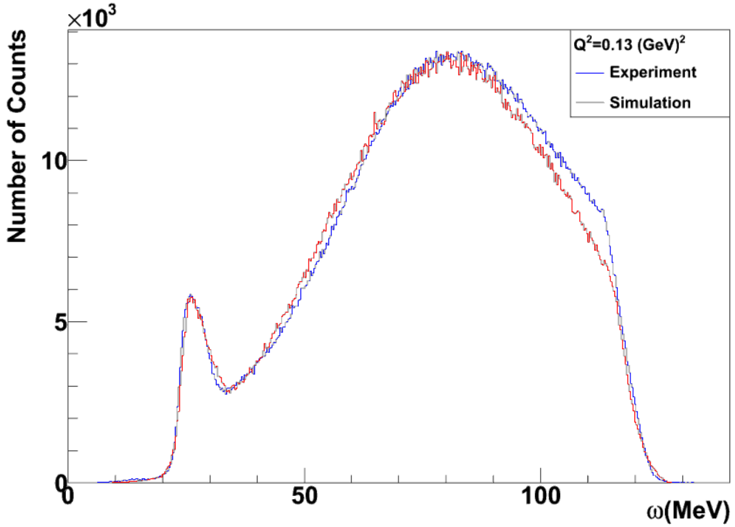
Events Selection

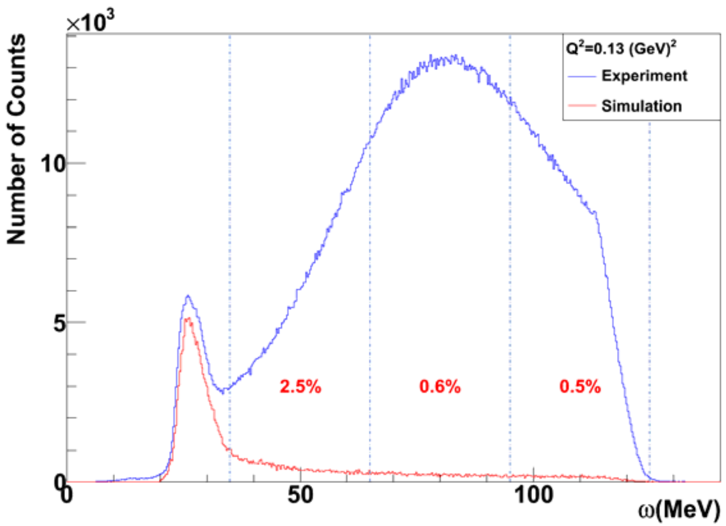






Elastic Tail Contamination



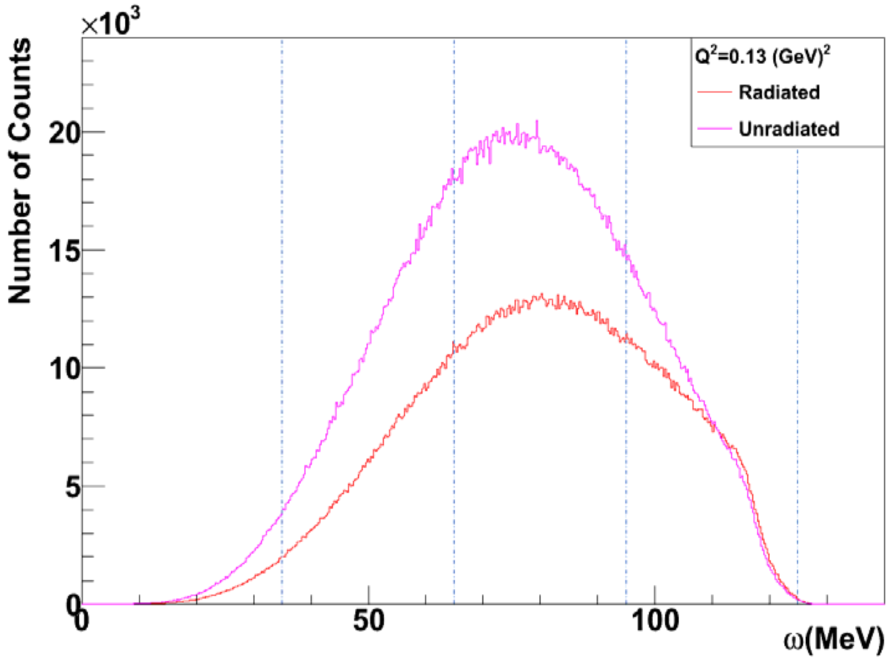


Elastic tail was subtracted from the quasi-elastic peak.

Only matters for Q^2 =0.13 GeV^2

For Q^2 =0.46 and 0.96 GeV^2, elastic tail contaminations were very small, can be neglected.

Radiative Corrections

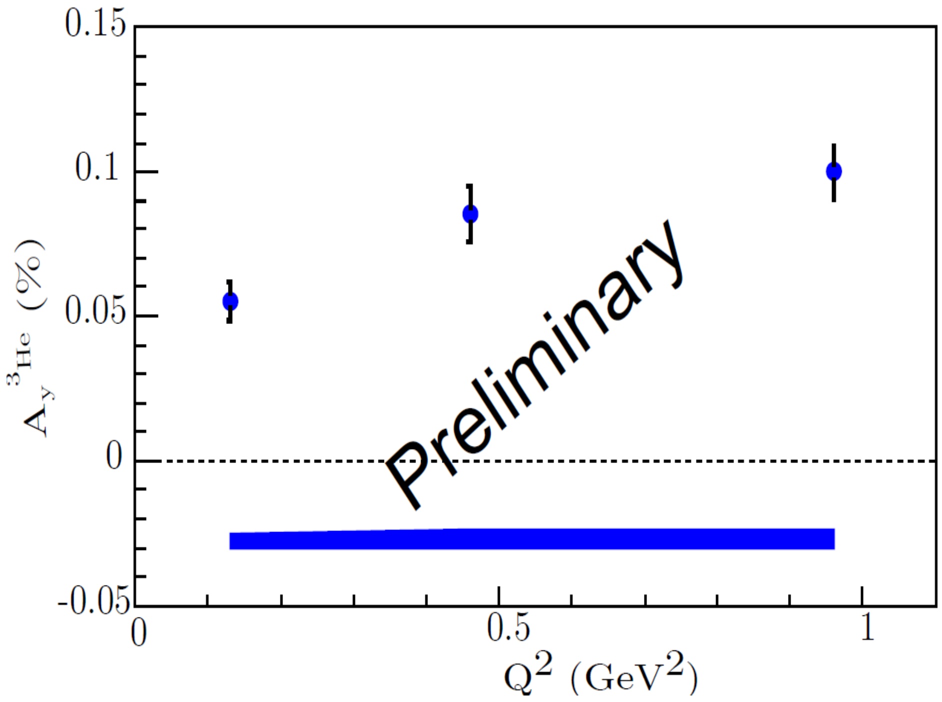


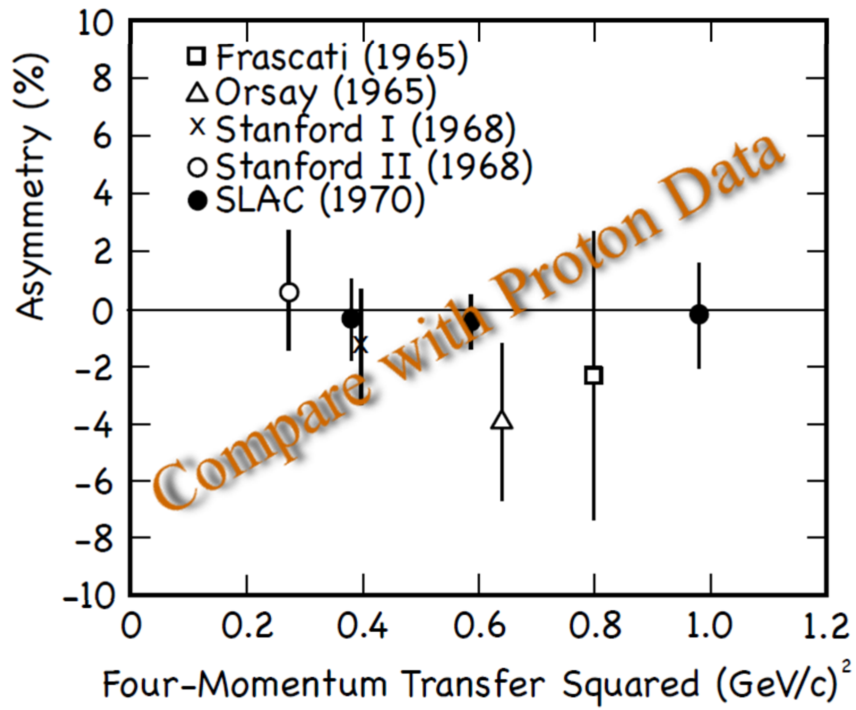
The main purpose of radiative correction in this experiment is to find the correct kinematics.

An example of kinematics shift

Bin center shifts were very small for all three kinematic settings in this experiment (<2MeV).

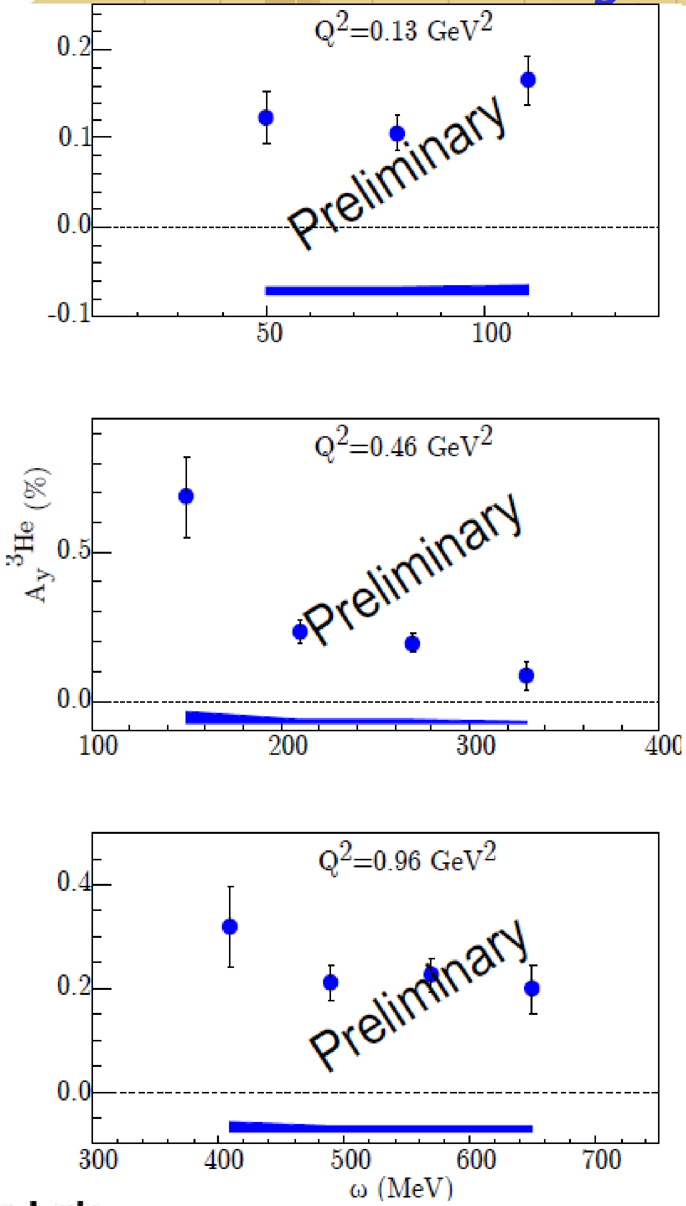
Preliminary Results





- The asymmetries are clearly non-zero.
- Precision is an order of magnitude improved over.

Preliminary Results



Preliminary Helium-3 results as a function of energy transfer ω.

With nitrogen dilution and target polarization corrected.

With radiative effects corrected.

Systematic uncertainty dominated by target polarization.

Summary

- Electron A_y results from QE region:
  - It is the first time to measure A_y with high-precision (~10^{-4} level) on a neutron target.
  - Helium-3 asymmetries were extracted at Q^2 at 0.13, 0.46 and 0.96 GeV^2.
  - For Q^2=0.96 GeV^2 data, original analysis was done by B. Zhao, two independent cross checks had been done by Ellie and Yawei Zhang.
  - Clear non-zero asymmetries were observed for all Q^2 points.

- Future Plan:
  - Proton dilution, extract the neutron asymmetry from Helium-3.
  - Finalize the systematic uncertainties.
  - Publish the paper.

Acknowledgement

- Thanks to the spokespeople:

  T. Averett (E05-015, E08-05), J.-P. Chen (E05-015), S. Gilad (E05-102), D. Higinbotham (E05-102, E08-005), X. Jiang (E05-015), W. Korsch (E05-102), B. E. Norum (E05-102), S. Sirca (E05-102), V. Sulkosky (E08-005).
- Graduate students:

  G.Jin, E.Long, M.Mihovilovič, Y.-W.Zhang
- Hall A collaborations.

Backup 1

$$A_y = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}} = \sqrt{\frac{2\,\varepsilon\,(1+\varepsilon)}{\tau}}\,\frac{C_B(\varepsilon, Q^2)}{d\sigma}$$

$$\times \left\{ -G_M \mathcal{I}\left(\delta\tilde{G}_E + \frac{\nu}{M^2}\tilde{F}_3 \right) + G_E \mathcal{I}\left(\delta\tilde{G}_M + \left(\frac{2\varepsilon}{1+\varepsilon}\right)\frac{\nu}{M^2}\tilde{F}_3 \right) \right\}$$

In terms of GPD moments

Y.C. Chen etc., PRL 93, 122301 (2004)

A measurement of Ay has sensitivity to GPD model input