# Normal beam spin asymmetries during the $G^0$ forward angle measurement

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for the $G^0$ collaboration

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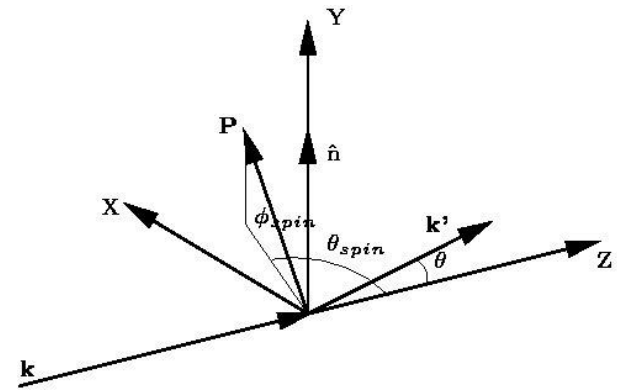
# Physics motivation

- The imaginary part of the 2-photon exchange amplitude produces a cross section dependence on the angle between the electron polarization vector, **P**, and the scattering plane:

$$\sigma = \sigma_0 \left[ 1 + A_n \mathbf{P} \cdot \hat{\mathbf{n}} \right]$$




- If the electron is not longitudinally polarized, the normal beam spin asymmetry will contribute to the asymmetry measured by the $G^0$ detectors:

$$A_{meas}(\theta, \phi) = P \cos(\theta_{spin}) A_{PV}(\theta) + P \sin(\theta_{spin}) \sin(\phi - \phi_{spin}) A_n(\theta)$$

- If the electron polarization is transverse, the vector analyzing power can be extracted from the azimuthal dependence of the asymmetry
- Both SAMPLE and PVA4 have published measurements of the vector analyzing power; recent or proposed measurements at HAPPEX-II and PVA4, in addition to $G^0$

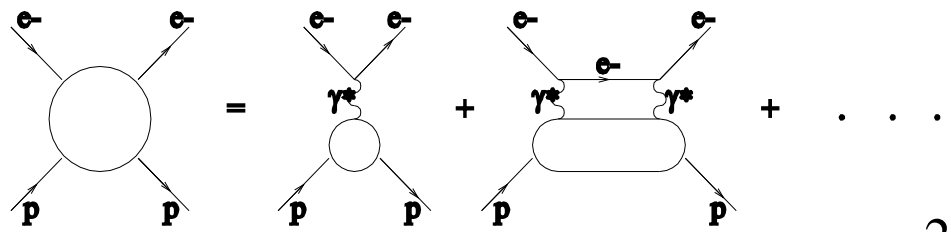
# What can $A_n$ reveal about two-photon amplitudes?

- The vector analyzing power is defined as:

$$A_n = \frac{Tr\{M(\theta)\Sigma_n M^\dagger(\theta)\}}{Tr\{M(\theta)M^\dagger(\theta)\}}$$

- Expanding the amplitude to second order,

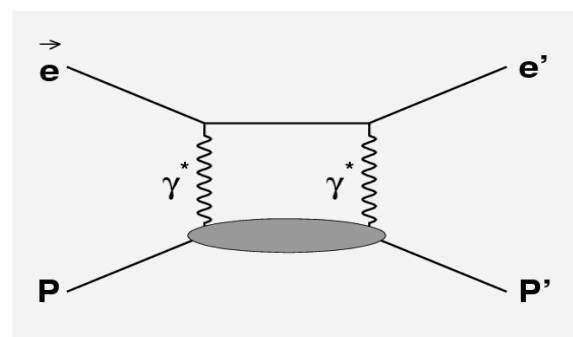
$$M = M_{Born} + M_{2\gamma} + \ldots$$




- Then $A_n$ depends on the imaginary part of $M_{2\gamma}$:

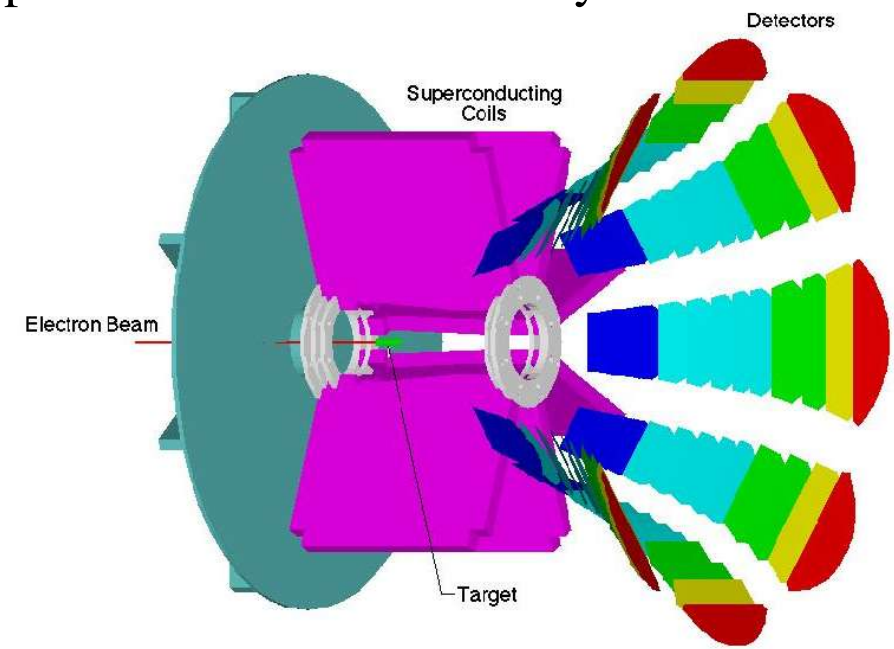
$$A_n = \frac{2 M_{Born} \Im\{M_{2\gamma}\}}{|M_{Born}|^2}$$

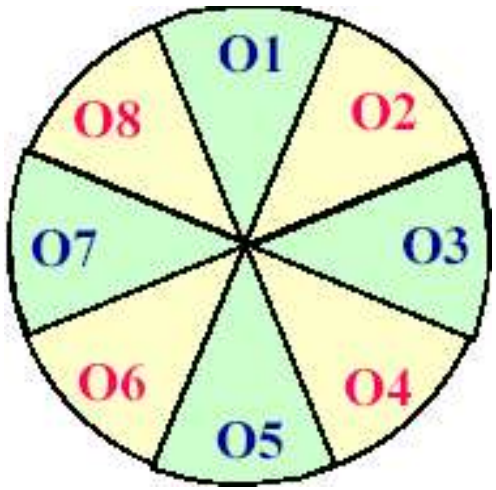
- The predictions of the asymmetry are sensitive to the physics of the intermediate hadronic state.
  - HB$\chi$PT: low energy
    (L. Diaconescu & M. J. Ramsey-Musolf, nucl-th/0405044)
  - Resonance region: moderate energy
    (B. Pasquini & M. Vanderhaeghen, hep-ph/0405303)
  - GPD: high energy
    (M. Gorchtein, P.A.M. Guichon, M. Vanderhaeghen, Nucl.Phys.A 741:234-248, 2004)



# The $G^0$ forward angle measurement

- Runs in Hall C at JLab: 3 GeV longitudinally polarized electrons scatter from a 20 cm LH2 target
- Recoil protons are focused in a superconducting magnet, and detected in 8 azimuthally symmetric detector packages with 16 detectors in each octant.
- Parity violating asymmetries of 2-20 ppm are measured.
- $A_n$ is a physics background to $G^0$; 5% of the $G^0$ data was taken with transverse polarization to minimize systematic uncertainties



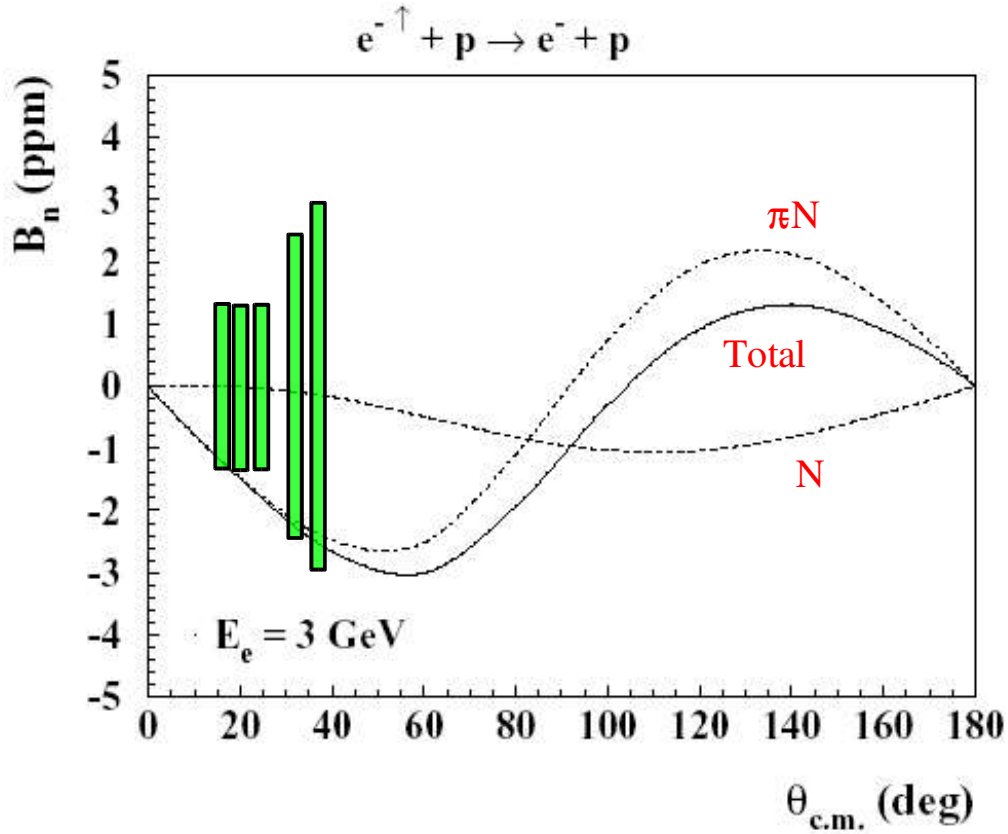

Octant Layout (looking DS)

# Expected precision on $A_n$ for forward angle $G^0$

- Data collection took place over 22-26 March 2004:
  39 hrs (30 parity hrs) on LH2; 5.8 hrs (3.8 parity hrs) on Al.

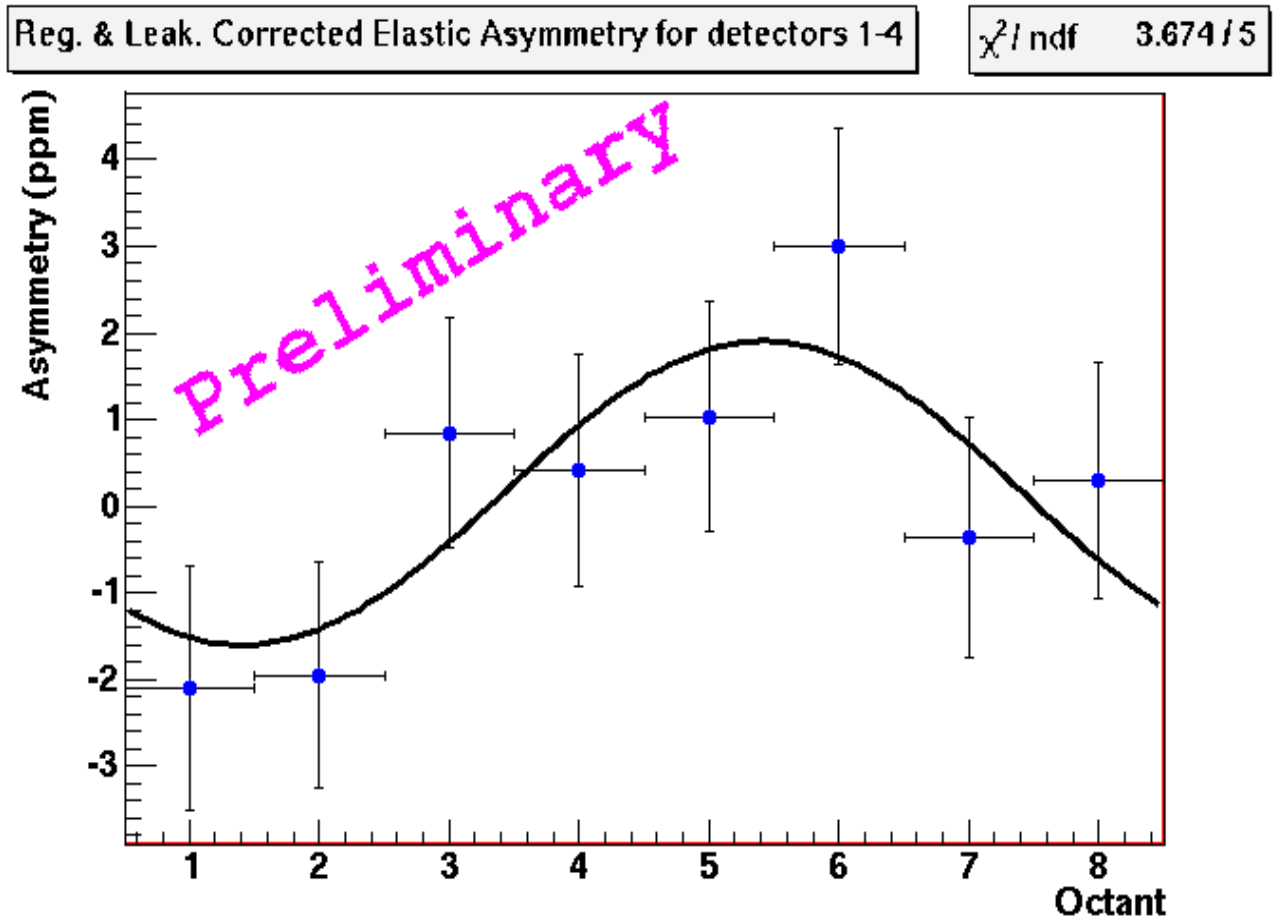
- Projected statistical errors for the elastic scattering peak on LH2

| Detectors | $\langle\theta_{CM}\rangle$ | Proj. Stat. Error |
|---|---|---|
| 1-4 | 19.03 | 1.3 ppm |
| 5-8 | 21.65 | 1.3 ppm |
| 9-12 | 26.12 | 1.3 ppm |
| 13-14 | 32.35 | 2.4 ppm |
| 15 | 37.4 | 2.9 ppm |



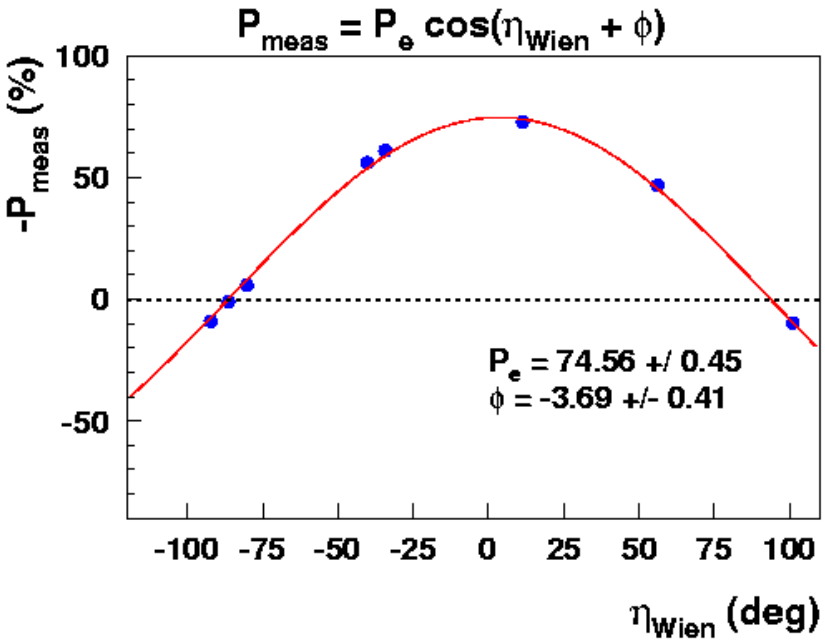

Calculation at the $G^0$ forward angle beam energy using the elastic state, and π-N intermediate states with W<2 GeV. (B. Pasquini & M. Vanderhaeghen, hep-ph/0405303)

# Asymmetries & required corrections



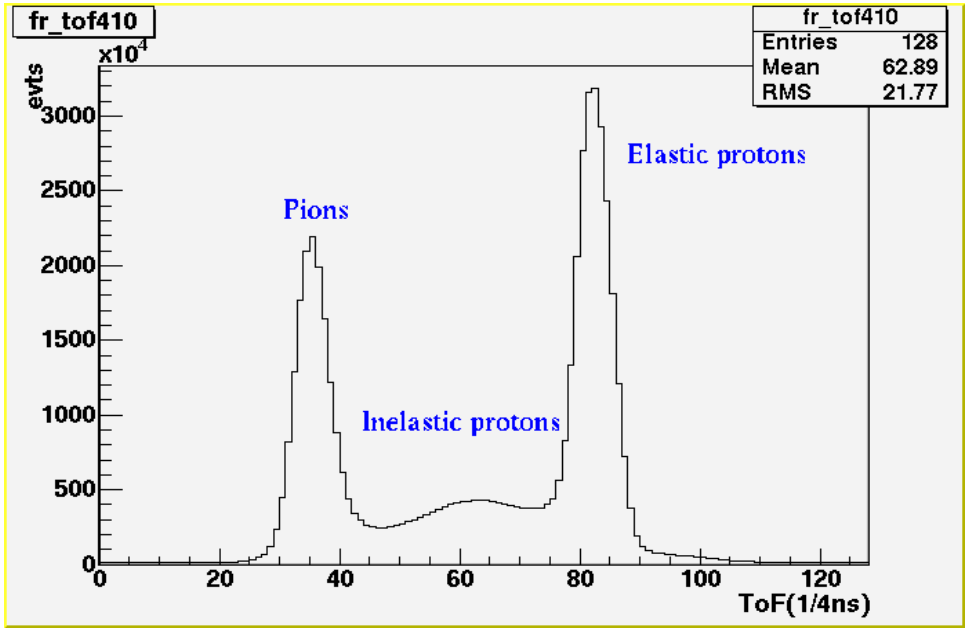

- LH2 data with leakage correction and beam parameter regression only. Does not include background corrections, target wall subtraction, beam polarization, detector alignment corrections.
  Multiplied by a blinding factor in the range of 0.75-1.25.

# Two dominant systematic errors




- Beam polarization: ~10% $A_{meas}$
  - Hall C Moller is not sensitive to $P_{\perp}$
  - Polarization direction and magnitude were estimated from polarization vs. Wien angle

- Backgrounds: 3% to 14% $A_{meas}$
  - There is some contamination from other particles in the "elastic" asymmetry
  - Corrections can be made from data in the inelastic peaks

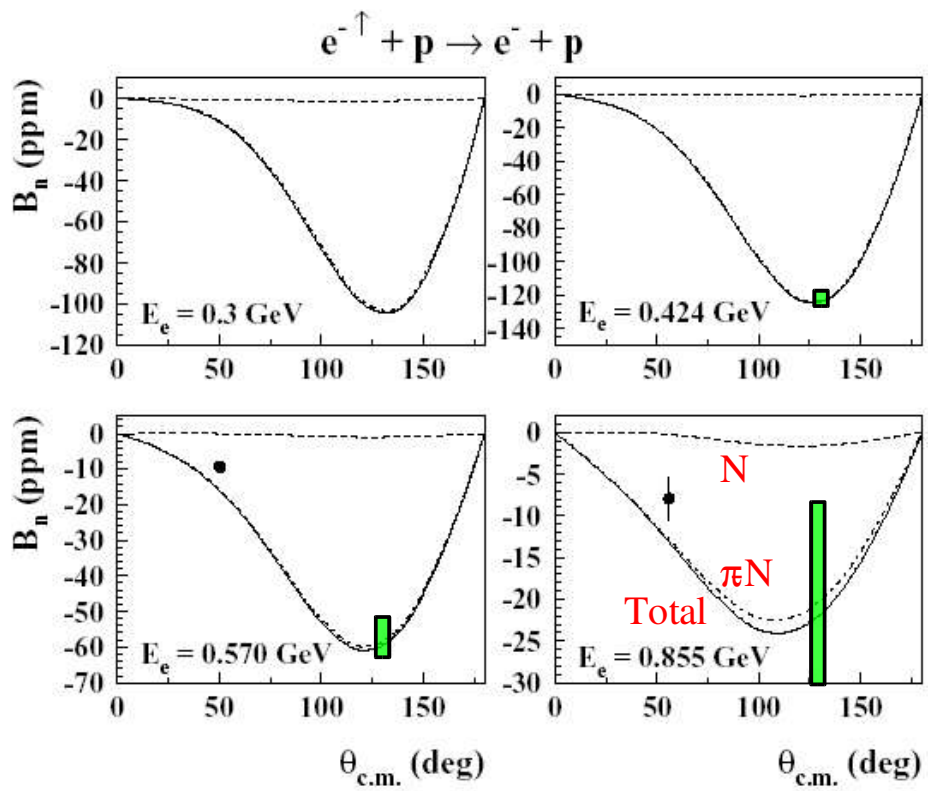


# Backward angle measurements within $G^0$

- Beam time to constrain systematic errors in the $G^0$ $A_{PV}$: 48 hours of parity quality running on LH2 at each of the three backward angle energies
- Modifications to the Moller may still be possible to reduce systematic error from $P_\perp$

- This would give this precision, at $\theta_{CM} \sim 130^\circ$, assuming 80 $\mu$A beam current and 70% polarization

| Beam Energy | $\langle Q^2 \rangle$ | Stat. Error |
|---|---|---|
| 0.424 GeV | 0.3 | 3.4 ppm |
| 0.585 GeV | 0.5 | 5.8 ppm |
| 0.799 GeV | 0.8 | 11 ppm |




Calculations from B. Pasquini & M. Vanderhaeghen (hep-ph/0405303); Data from A4 collab.

# Conclusions

- We have made measurements of the beam normal asymmetry for elastic e-p scattering at a beam energy of 3 GeV for center of mass angles of 19°-38°.
  - The final statistical precision on these measurements will be a few ppm.
  - The systematic errors may be 10-20% of the measured asymmetry.
- We plan to make measurements at backward angles, with center of mass angles of about 130°, at beam energies of 799, 585, and 424 MeV.
  - The projected statistical error is between 3 and 11 ppm for measurements taken to minimize systematic errors on the $G^0$ PV asymmetry.
  - Systematic errors from beam polarimetry could be reduced by modifying the Moller to be sensitive to transverse polarization.