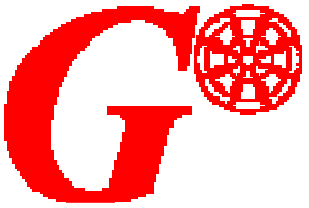


Transverse Beam Spin Asymmetries from the G^0 Experiment

Sarah K. Phillips

The College of William and Mary

on behalf of the G^0 Collaboration

Carnegie-Mellon, CalTech, William and Mary , Grinnell College , Hampton University, IPN-Orsay, LPSC-Grenoble, JLab, Louisiana Tech, NMSU, TRIUMF, UIUC, U. Kentucky, U. Manitoba, U. Maryland, UNBC, U. Winnipeg, Virginia Tech, Yerevan

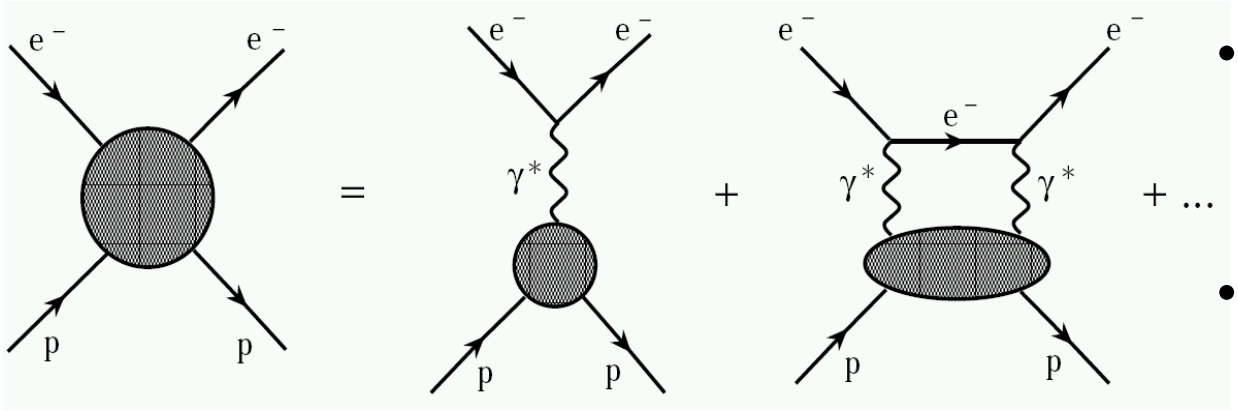
Hall C Meeting, Jefferson Lab, January 25, 2007

The College of WILLIAM & MARY

Transverse Beam Spin Asymmetries

- Elastic scattering of transversely polarized electrons from unpolarized nucleons.
- With transverse electron polarization, A_n can be extracted from the azimuthal dependence of the measured asymmetries.

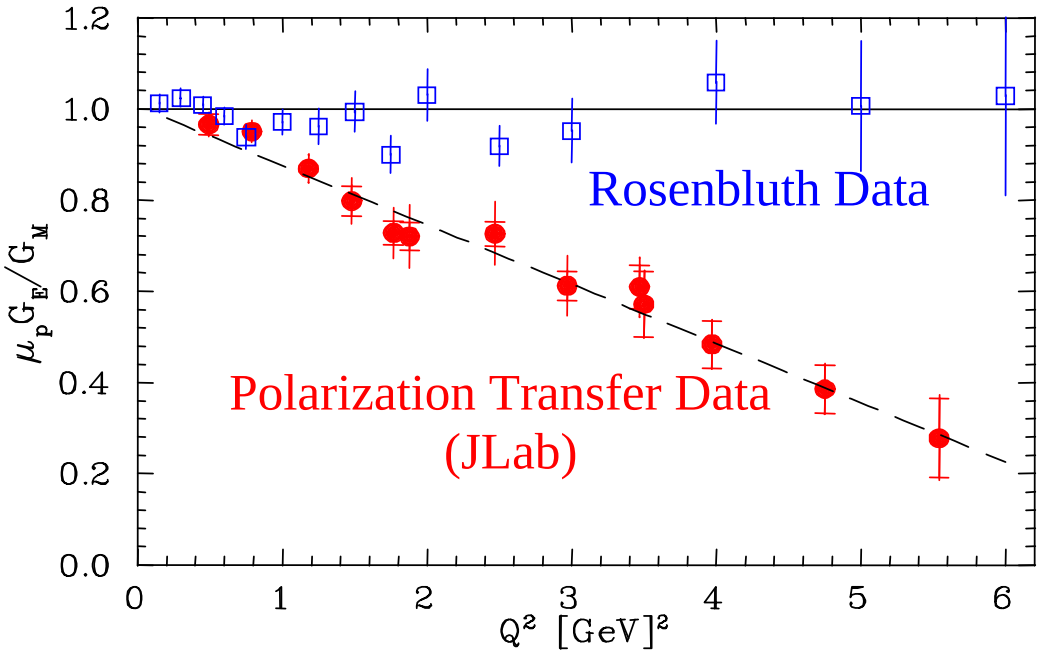
$$A_{\perp}^{m} = \frac{\sigma_{\uparrow} - \sigma_{\downarrow}}{\sigma_{\uparrow} + \sigma_{\downarrow}} = \left| A_n \right| \sin\left(\phi + \phi_0\right)$$



- A_n arises from interference of the one-photon and two-photon exchange amplitudes
- A_n comes from the imaginary part of the two photon exchange amplitude.
- Vanishes in Born approximation

Why is Two-Photon Exchange Interesting?

- A_n (from ***imaginary*** part) is a possible source of systematic background to precision parity-violation experiments!



J. Arrington, Phys. Rev. C 68, 034325 (2003)

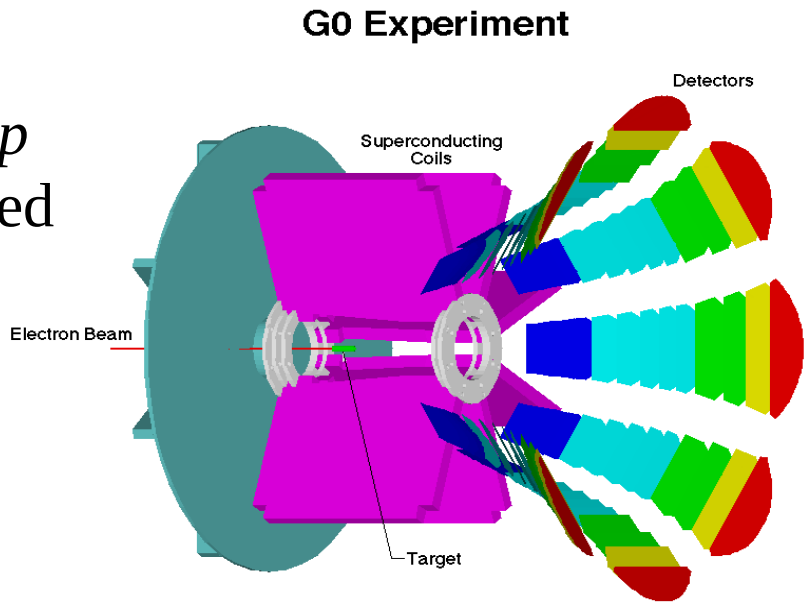
  - Measurements at various kinematics by SAMPLE, A4, HAPPEX, E158

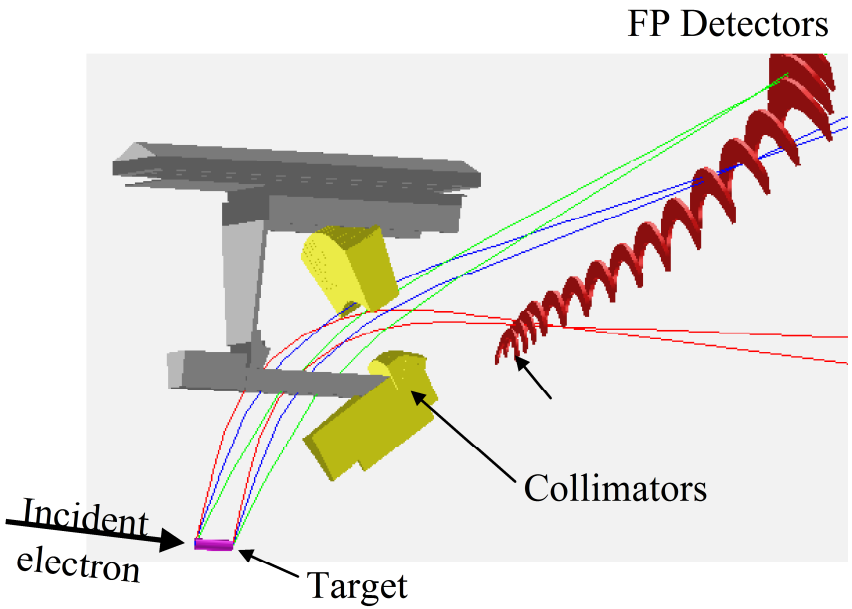
- ***Real*** part suggested as cause of discrepancy between Rosenbluth and polarization transfer elastic form factor data

- Both real and imaginary parts provide information on the treatment of hadronic intermediate states in box diagrams (as are found in some terms of radiative corrections).

The G^0 Forward-Angle Measurement

- Experiment measures asymmetries of the order of a few ppm from parity-violating *e-p* elastic scattering $\rightarrow$ ***longitudinally*** polarized electrons from an unpolarized LH_2 target.
- Full range of Q^2 (0.12 – 1.0 $(GeV/c)^2$) obtained in one energy setting (3 GeV).





- Azimuthally-symmetric spectrometer focuses recoil protons by Q^2 into segmented focal plane scintillation detectors
- Time-of-flight separates protons from pions; custom electronics count scattered particles

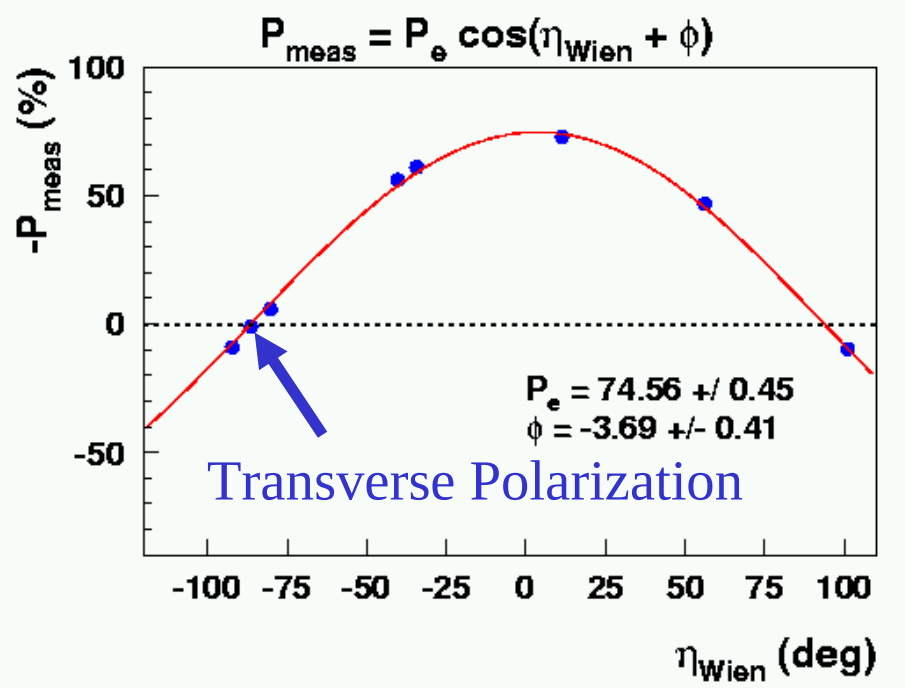
→ forward angle run completed

→ backward angle run in progress

D.S. Armstrong et al, PRL 95, 092001 (2005)

Transversely-Polarized Electron Beam

- Electron beam polarized in the plane of the accelerator
- Wien filter used to tune the spin for longitudinal or transverse spin in the Hall C.
- Beam properties setup same as the primary parity-violation experiment; beam quality comparable to longitudinal running.



- Hall C Møller polarimeter unable to directly measure transverse beam polarization, so polarization determined indirectly.

Transverse polarization: 74.32±1.02 %

Transverse Analysis Overview

Raw ToF Yields

→ Correct for deadtime → $f_{dead} = 10 - 15\%$

Blind asymmetries

→ Correct for 499 MHz leakage beam → $\Delta A \approx +1.3 \pm 0.41$ ppm

→ Check for false asymmetries from helicity-correlated beam properties → $\Delta A < 0.12$ ppm

→ Correct for the background and its asymmetry → $\Delta A_{1-8} = 0.8 - 2.0$ ppm, $\Delta A_{9-12} = 0.2 - 6.0$ ppm

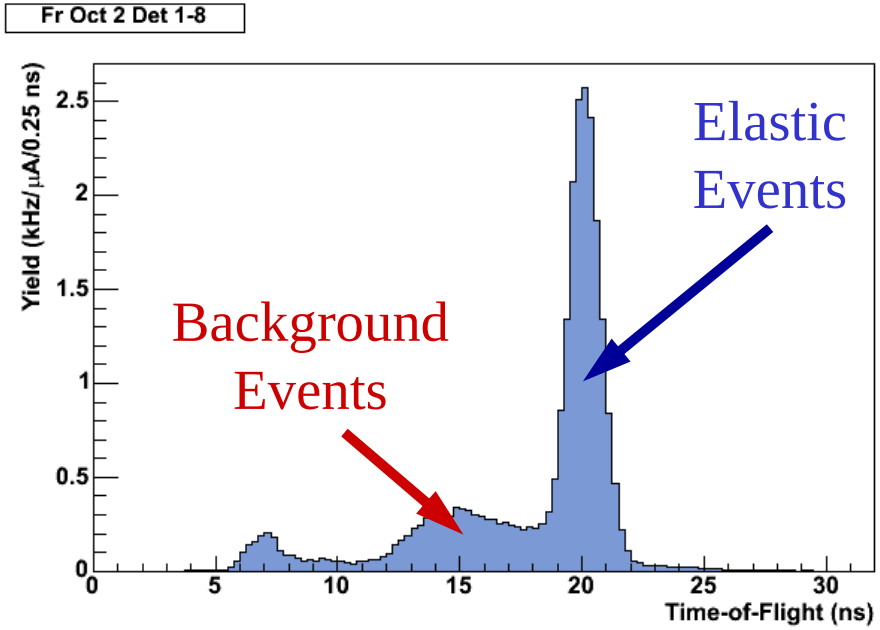
→ Correct for beam polarization → $P_{beam} \approx 0.7432 \pm 0.0102$

Unblind Asymmetries

→ Fit corrected asymmetries for the φ dependence and extract $A_\perp$

Transverse Data Set

- Took about 30 hours of data.
- The ToF spectra from the first 12 detectors were summed into two spectra: 1-8, 9-12.
- These two groups correspond to the following Q^2 and θ_{CM} values:

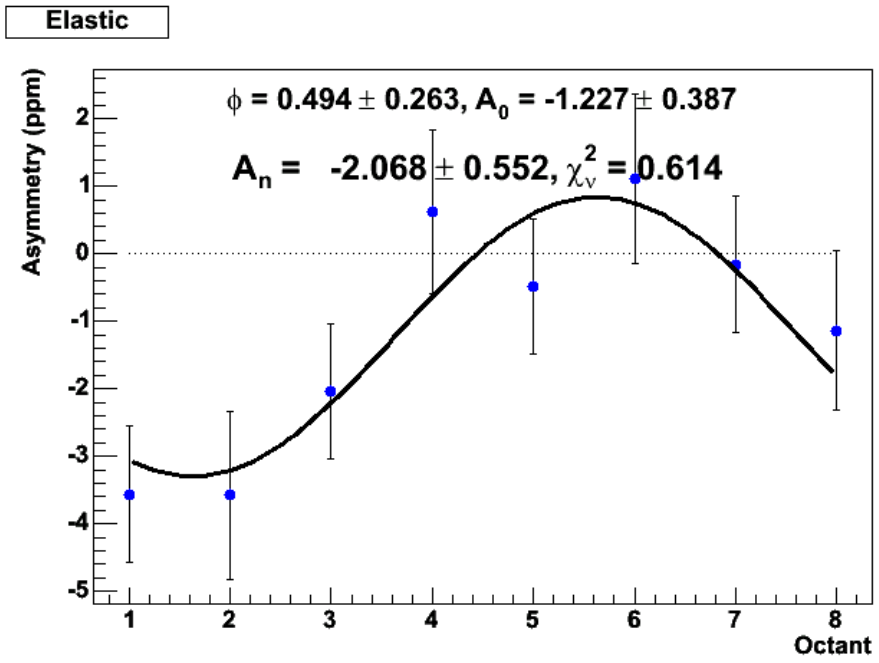


Detectors	θ_{CM}	$\langle\theta_{CM}\rangle$	Q^2 (GeV/c)^2
1 - 8	20.22°	18° – 23°	0.15 ± 0.02
9 - 12	25.91°	24° – 29°	0.25 ± 0.03

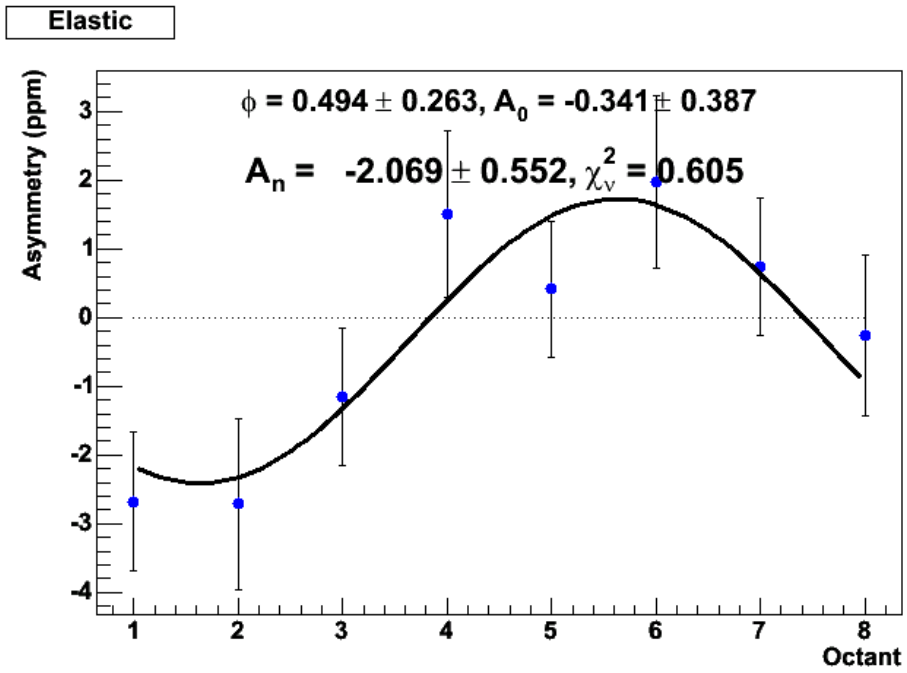
- Applied corrections (deadtime, etc.) before summing detectors.
- Defined one elastic cut and four cuts for background events.

Beam Leakage Correction

- The sinusoidal fits to the asymmetry data showed a global vertical offset (about – 1.5 ppm over all).
- The beam leakage correction took care of it.



No beam leakage correction



Beam leakage correction

(Asymmetries are blinded)

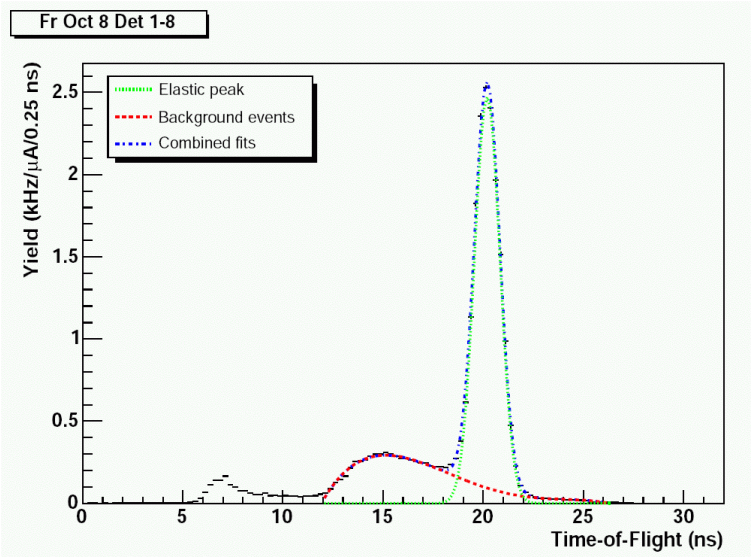
Background Correction

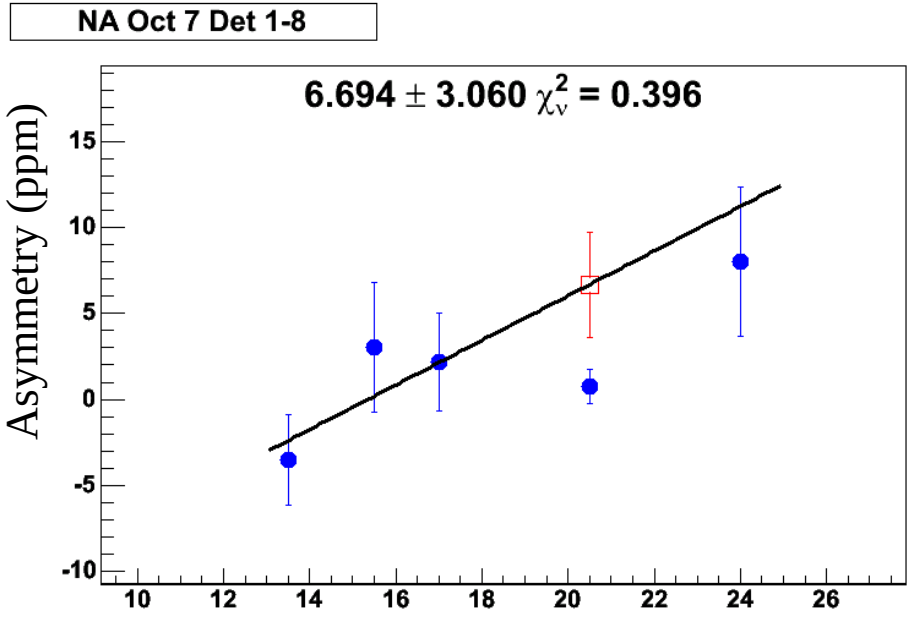
How do we determine A_{bkg}?

- Dilution factors found by fitting the elastic peak with a Gaussian and the background yield with a 4th-order polynomial.
- Asymmetries were fitted with a linear background and a constant elastic asymmetry.
  - Asymmetries vary smoothly across elastic peak.

$$f_s = \frac{Y_{elas}}{Y_{elas} + Y_{bkg}}$$

$$A_m = f_s A_{elas} + (1 - f_s) A_{bkg}$$





(***asymmetries are blinded***)

Systematic Errors

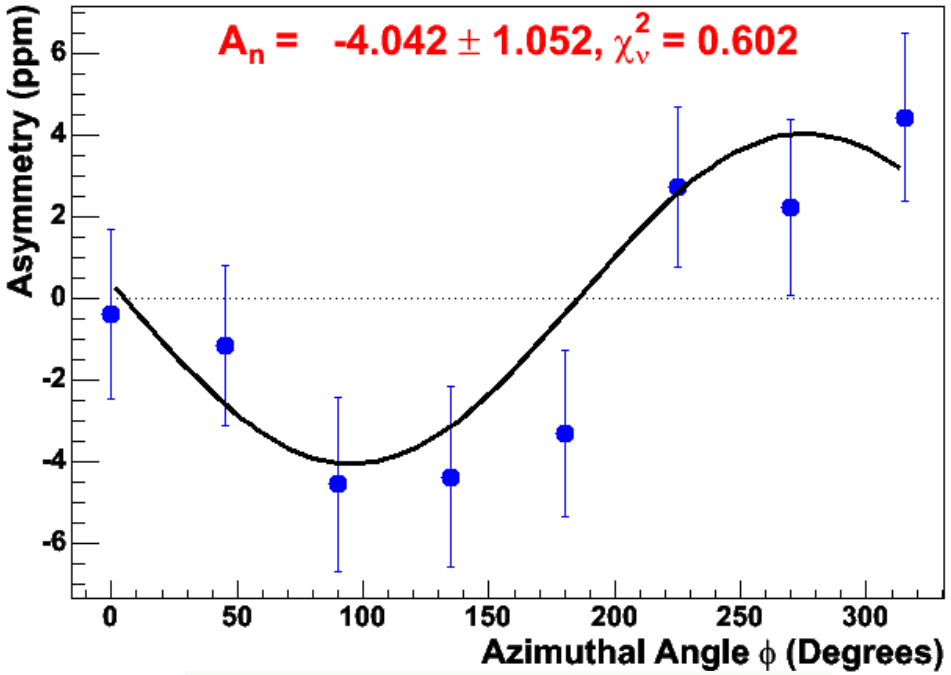
Source	***Uncertainty***
Helicity-correlated beam parameters	< 0.12 ppm
Leakage beam	0.41 ppm
Beam polarization	1.4%
Longitudinal polarization	0.002, 0.021 ppm
Background Correction	0.4 – 0.7 ppm, 0.8 – 3.9 ppm
Deadtime	0.05 ppm

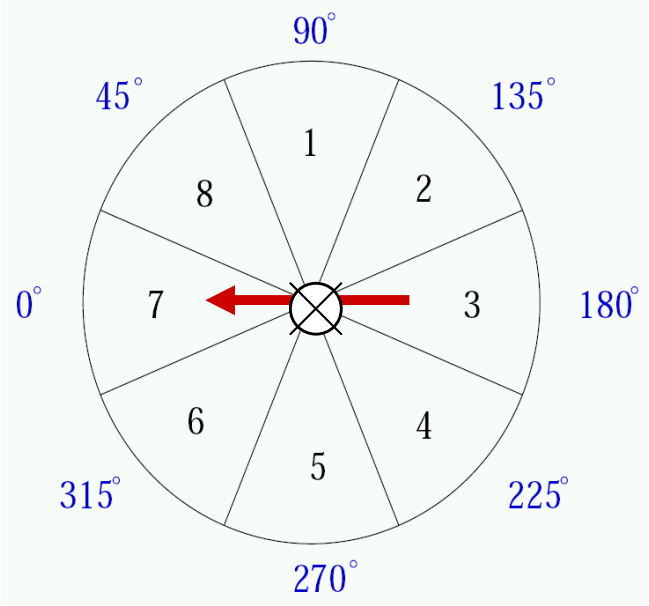
For example:

Octant 1, Detectors 1-8: $A_{elas} = -4.55 \pm 2.00_{stat} \pm 0.79_{syst}$ ppm

Transverse Beam Spin Asymmetry Results

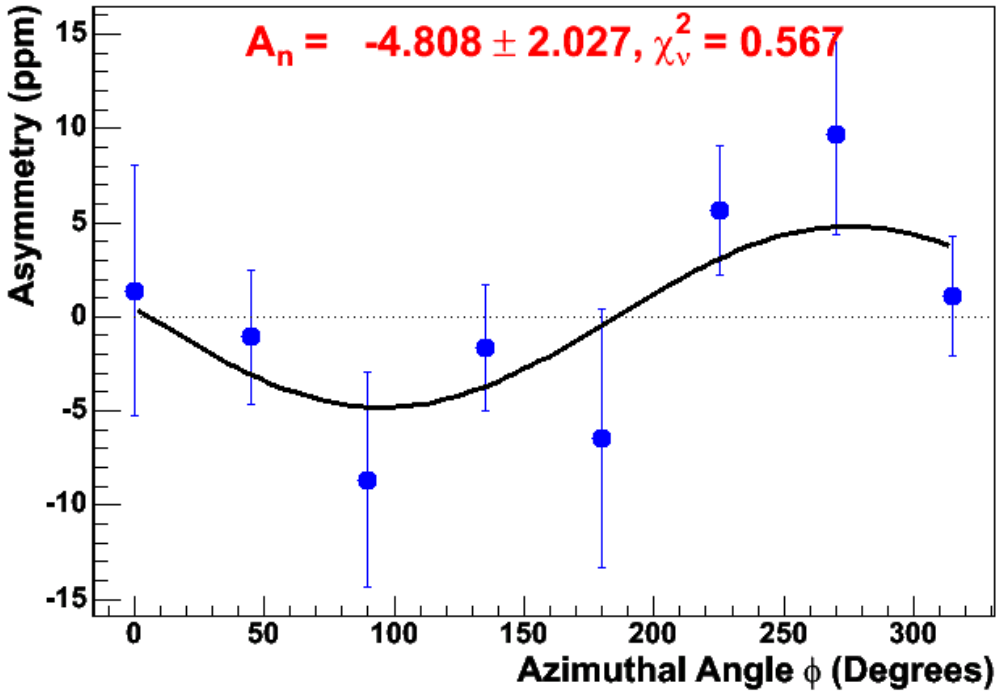
Q^2 = 0.15 (GeV/c)^2



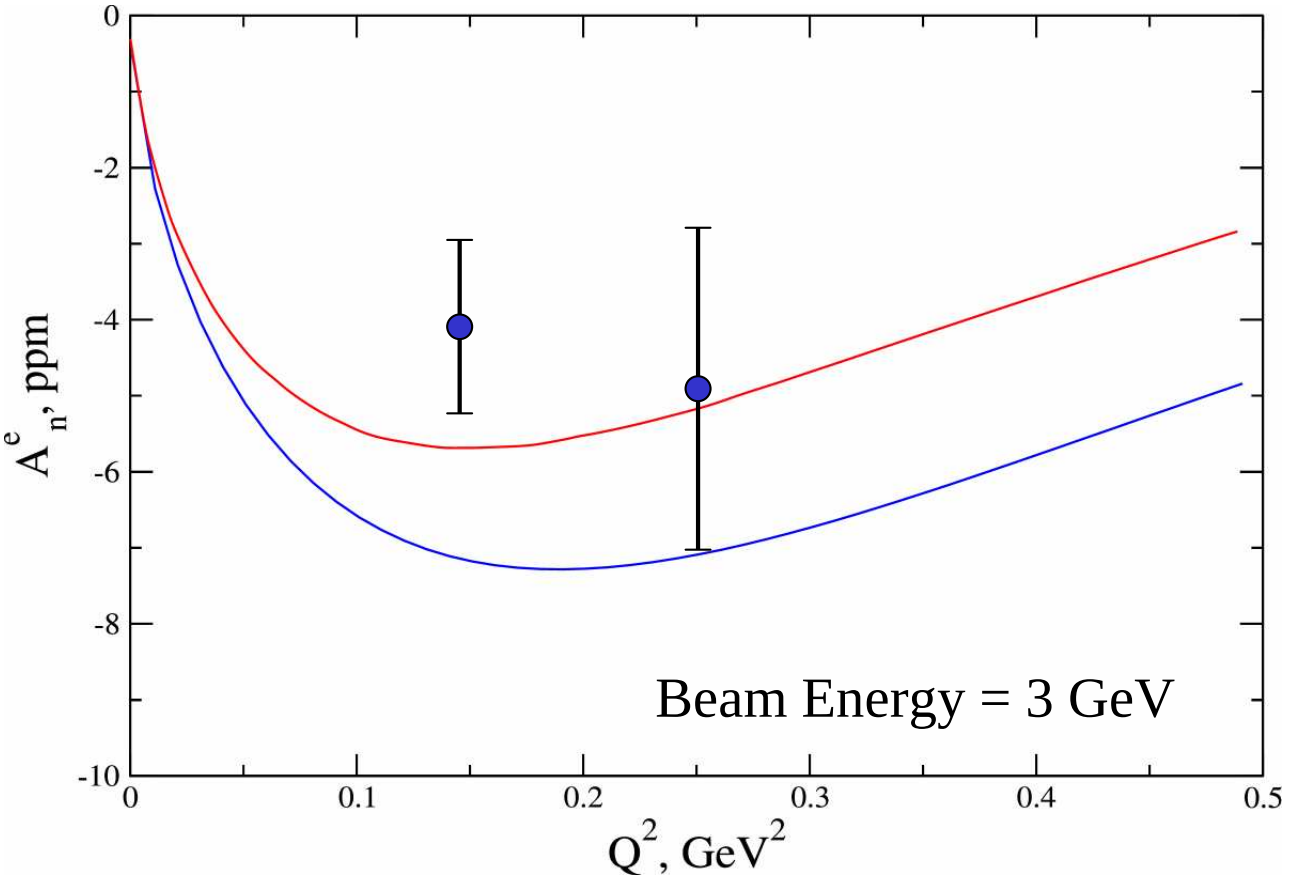


- Phase ϕ of sinusoidal fits constrained to the calculated precession through the Møller solenoid (~5.3°).
- Unblinded, corrected for all effects.

Q^2 = 0.25 (GeV/c)^2



Comparison to Theory



$A_n = -4.04 \pm 1.05$ ppm,
$Q^2 = 0.15 \pm 0.02\ (\mathrm{GeV}/c)^2$,
$\theta_{CM} = 20.22°$

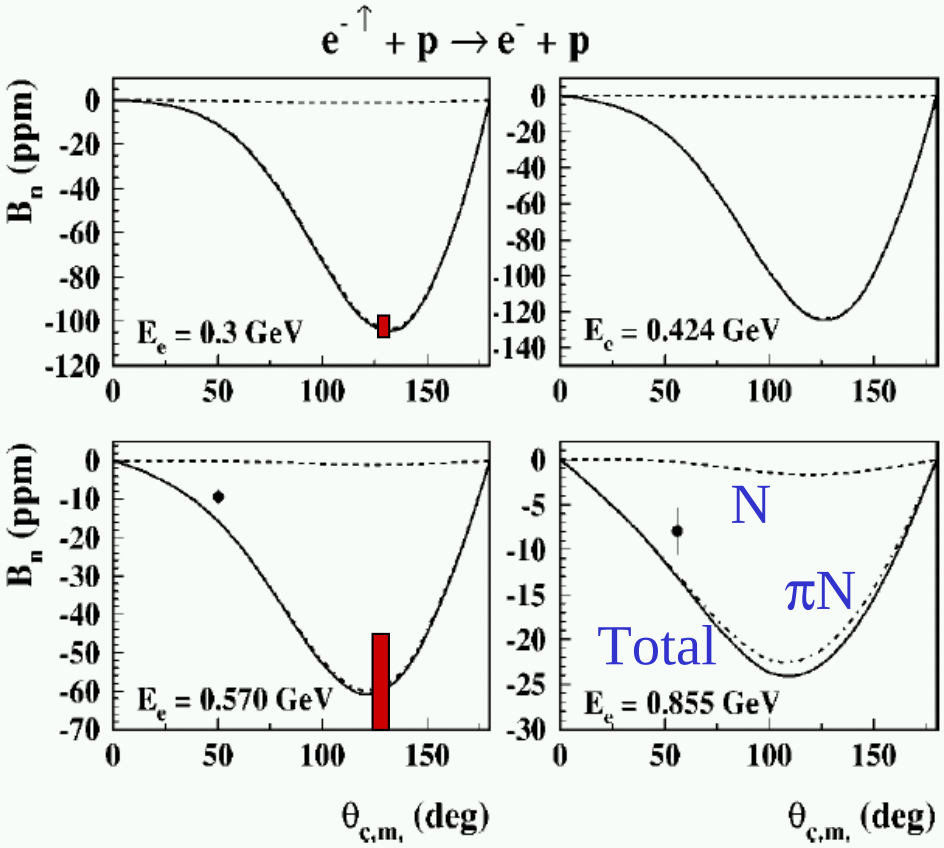
$A_n = -4.81 \pm 2.03$ ppm,
$Q^2 = 0.25 \pm 0.03\ (\mathrm{GeV}/c)^2$,
$\theta_{CM} = 25.91°$

M. Gorchtein, Phys.Rev.C73, 035213 (2006)

A. Afanasev & N. Merenkov, Phys.Lett.B599:48 (2004), hep-ph/0407167 v2

G^0 Backward-Angle Transverse Data

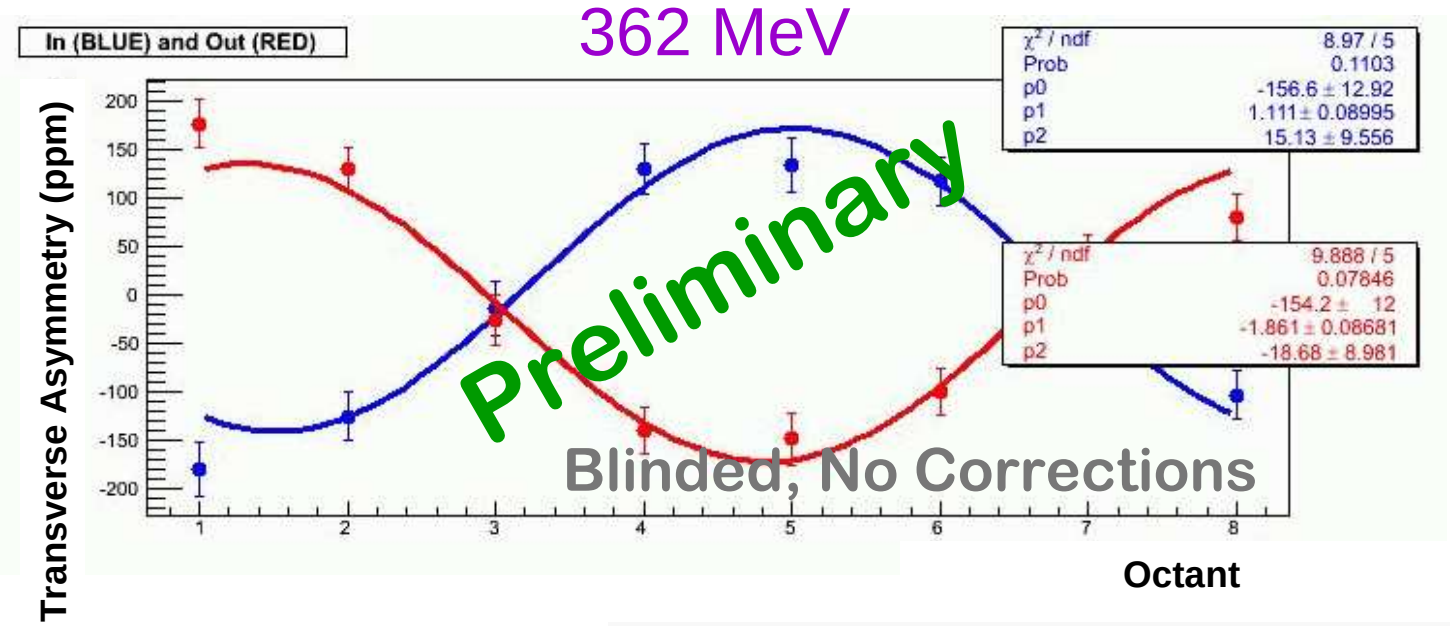
- Transverse beam spin asymmetry data is being taken on both LH_2 and LD_2 as part of the G^0 backward-angle measurement to constrain systematic errors.
- $\theta_{CM} \sim 130°$



Beam Energy	$\langle Q^2 \rangle$ (GeV/c)^2	Accumulated Charge	Statistical Error
0.362 GeV	0.23	3.59 C	~ 5-6 ppm
0.687 GeV	0.62	2.69 C	~ 15 ppm

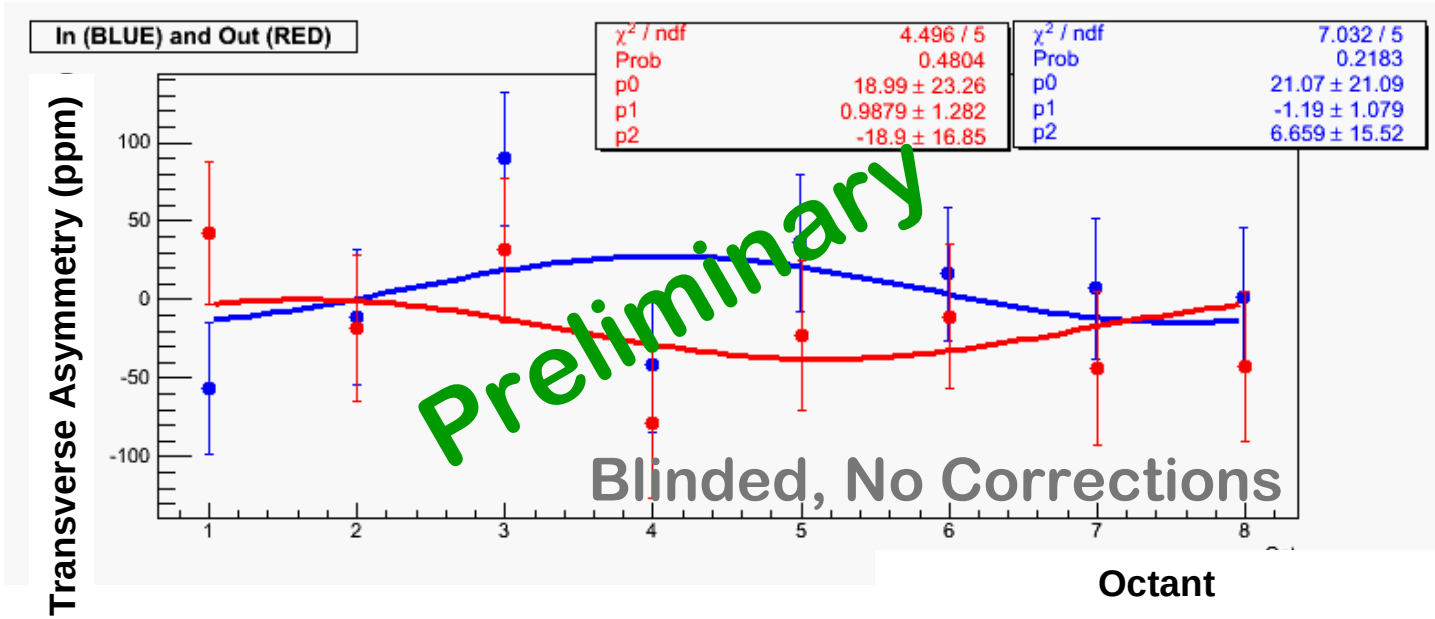
B. Pasquini & M. Vanderhaeghen, Phys. Rev. C70, 045206 (2004); Data from A4 collaboration

G^0 Backward-Angle Transverse Data



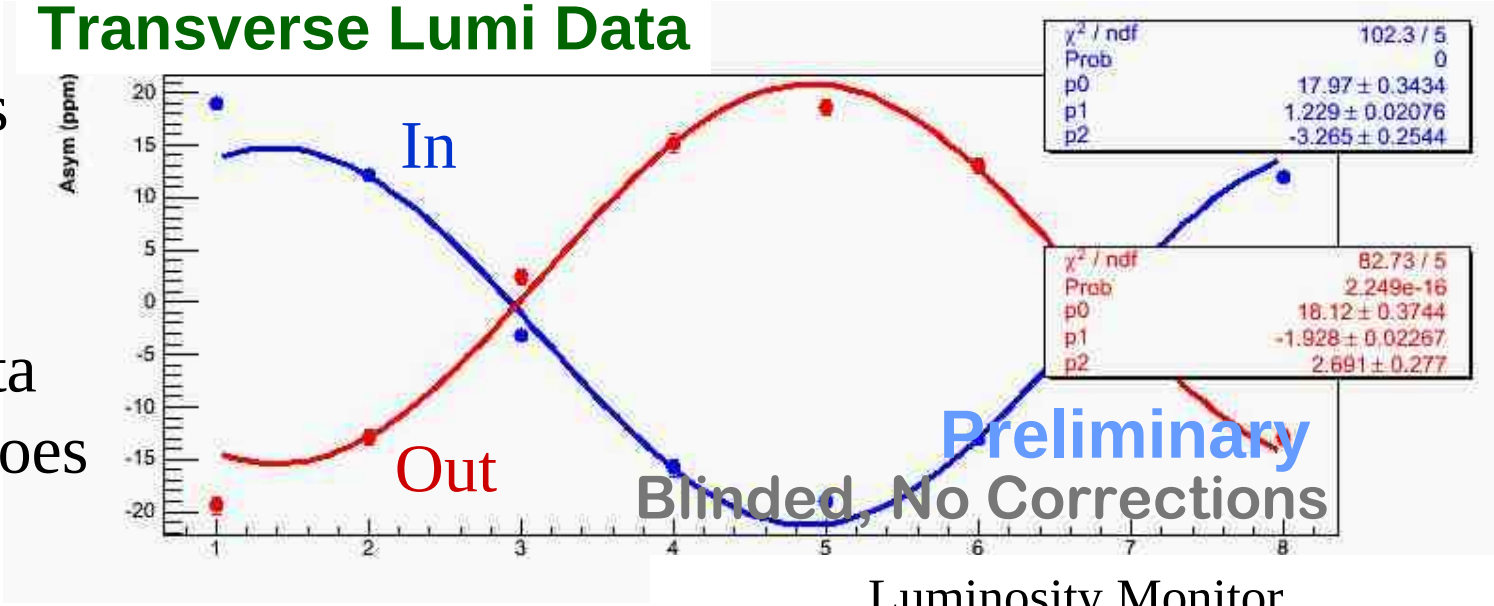
- Data analysis for these data underway
- Data blinded in both plots

- Time permitting, more data on LD_2 at 362 and 687 MeV, more statistics on LH_2.

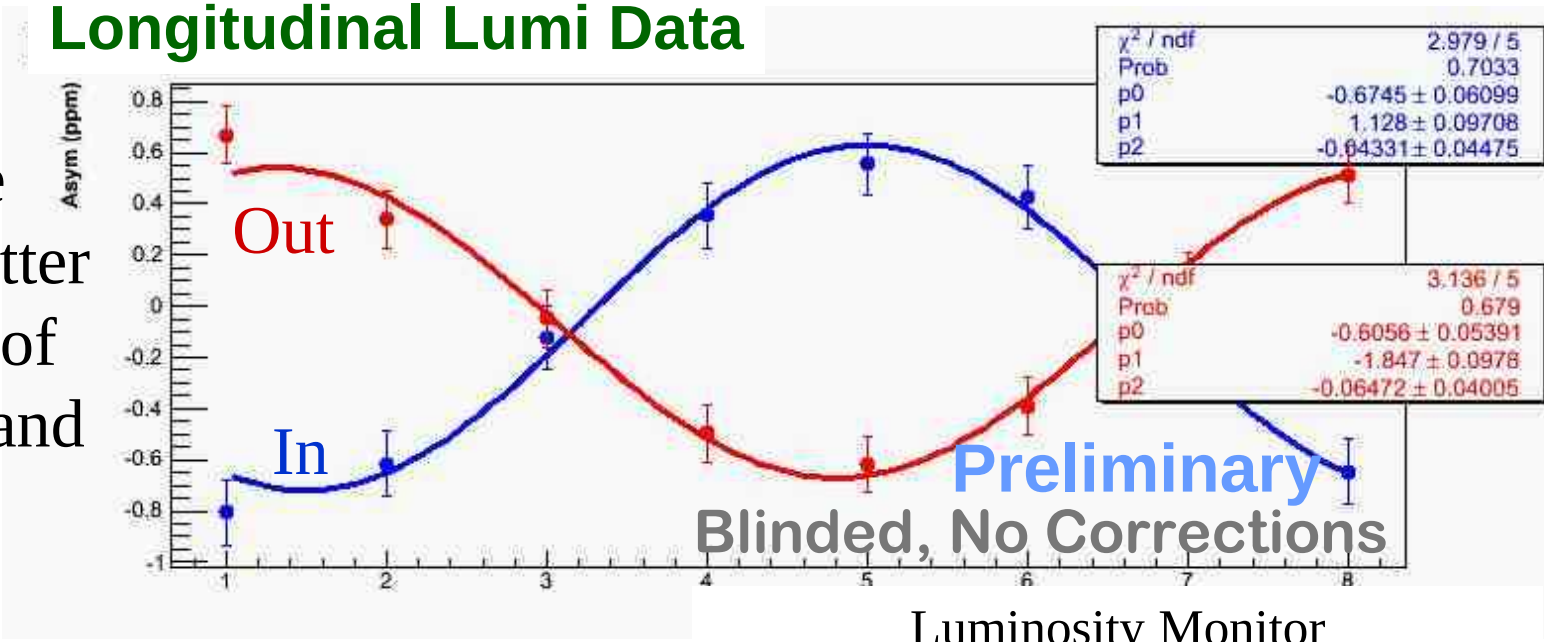


Backward-Angle Transverse Lumi Data

- Transverse data taken with lumis shows lovely sinusoidal trend
- Longitudinal data in this data set does too! (But much smaller – note scales)
- Gives a double check and a better understanding of spin direction and transverse corrections.



Luminosity Monitor



Luminosity Monitor

Conclusions

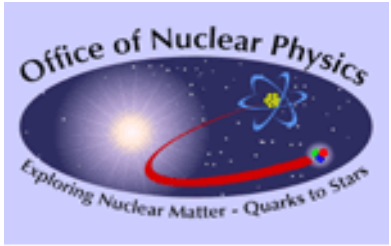
- We have made measurements of the transverse beam asymmetry for elastic e-p scattering at a beam energy of 3 GeV:

A_n (ppm)	Q^2 $(GeV/c)^2$	θ_{CM}
-4.04 ± 1.05	0.15 ± 0.02	20.22°
-4.81 ± 2.03	0.25 ± 0.03	25.91°

- Backward-angle data have been taken, at beam energies of about 362 and 687 MeV, with analysis underway and more to come.

Acknowledgements

- Many thanks to the people who were involved in this project: Paul M. King, David Armstrong, Dave Gaskell, Julie Roche, Steven P. Wells, Betsy Beise, Doug Beck, and the G^0 collaboration.
- The G^0 experiment is funded largely by CNRS (France), DOE (U.S.A.), NSERC (Canada), and NSF (U.S.A.)



Backup Slides!
Yay!

Measurements of A_n by Parity-Violation Experiments

Parity-violation experiments measure these asymmetries to assess possible systematic error contributions

- Published Results (on hydrogen targets):

	Beam Energy	θ_{CM}	A_n (ppm)
SAMPLE*	200 MeV	142°	− 16.4 ± 5.9
A4†	569 MeV	56°	− 8.59 ± 1.16
A4†	855 MeV	56°	− 8.52 ± 2.47

*S.P. Wells et al., Phys. Rev. C 63 (2001) 064001; †F.E. Maas et al., PRL 94 (2005) 082001

- To come in the near future:
  - HAPPEX at JLab – 3 GeV, forward angles, on H and ^{4}He
  - A4 at Mainz – 315 MeV, backward angles, on H
  - G0 at JLab – backward angles, currently running

Comparison to Theory

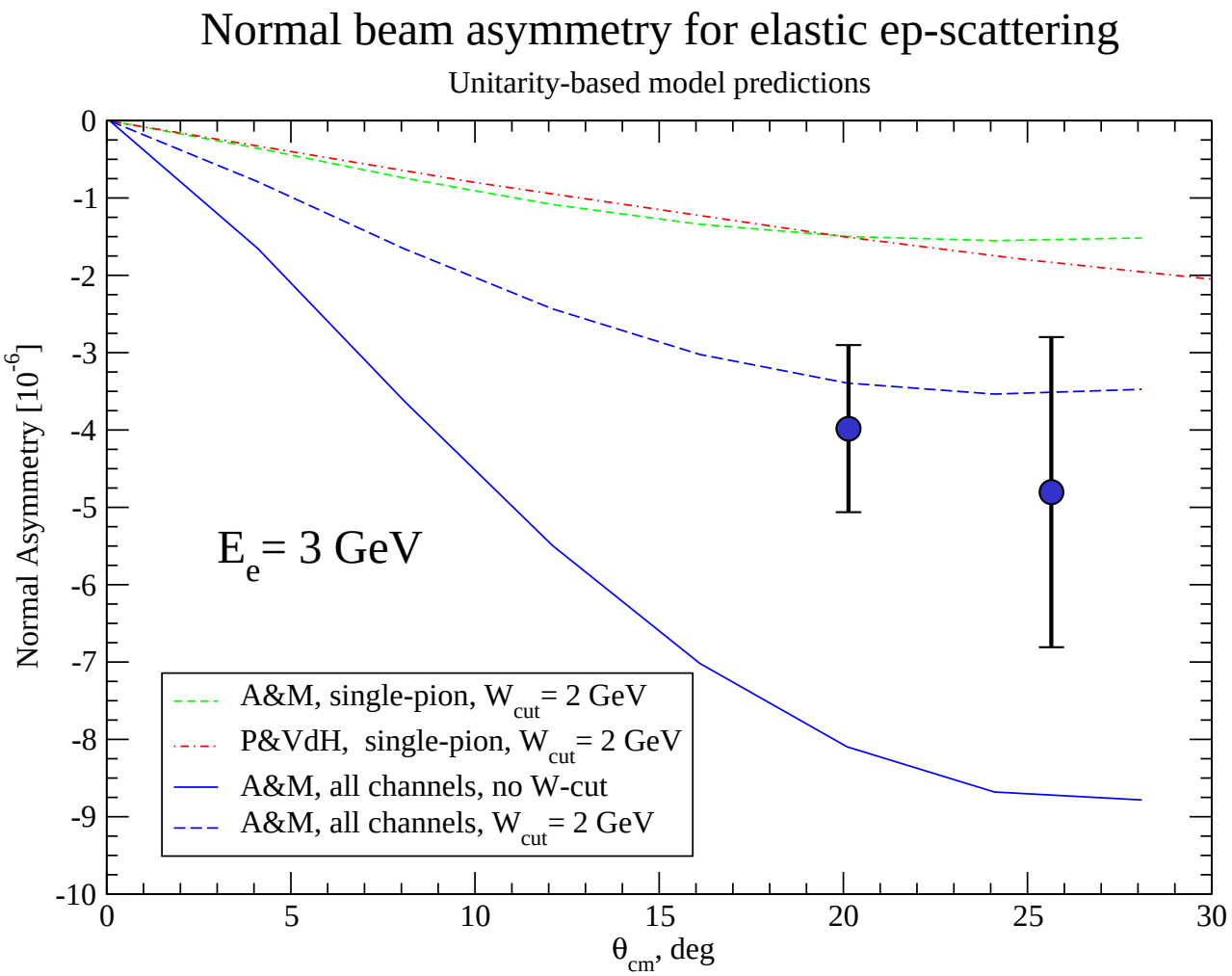


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Figure courtesy of A. Afanasev

A. Afanasev & N. Merenkov, Phys.Lett.B599:48 (2004), hep-ph/0407167 v2

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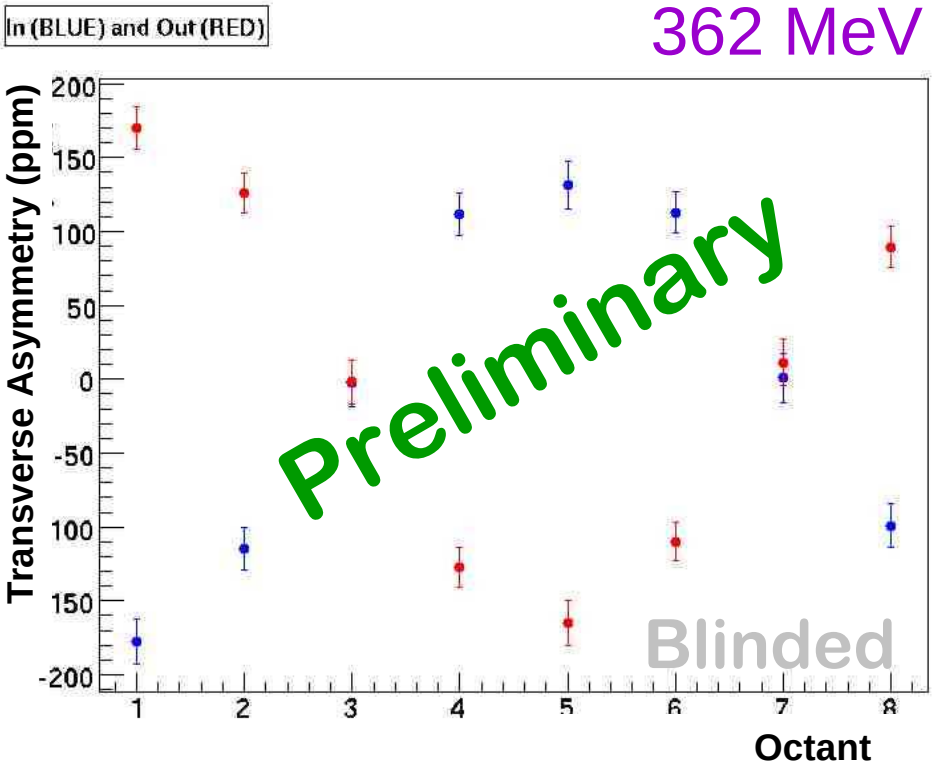

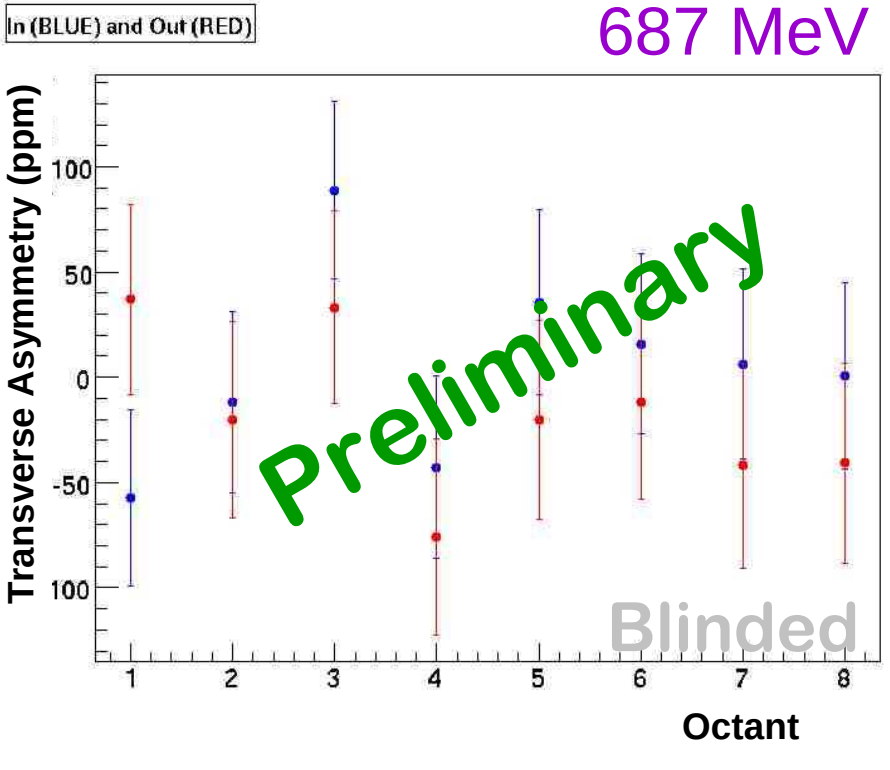

Transverse Analysis Overview