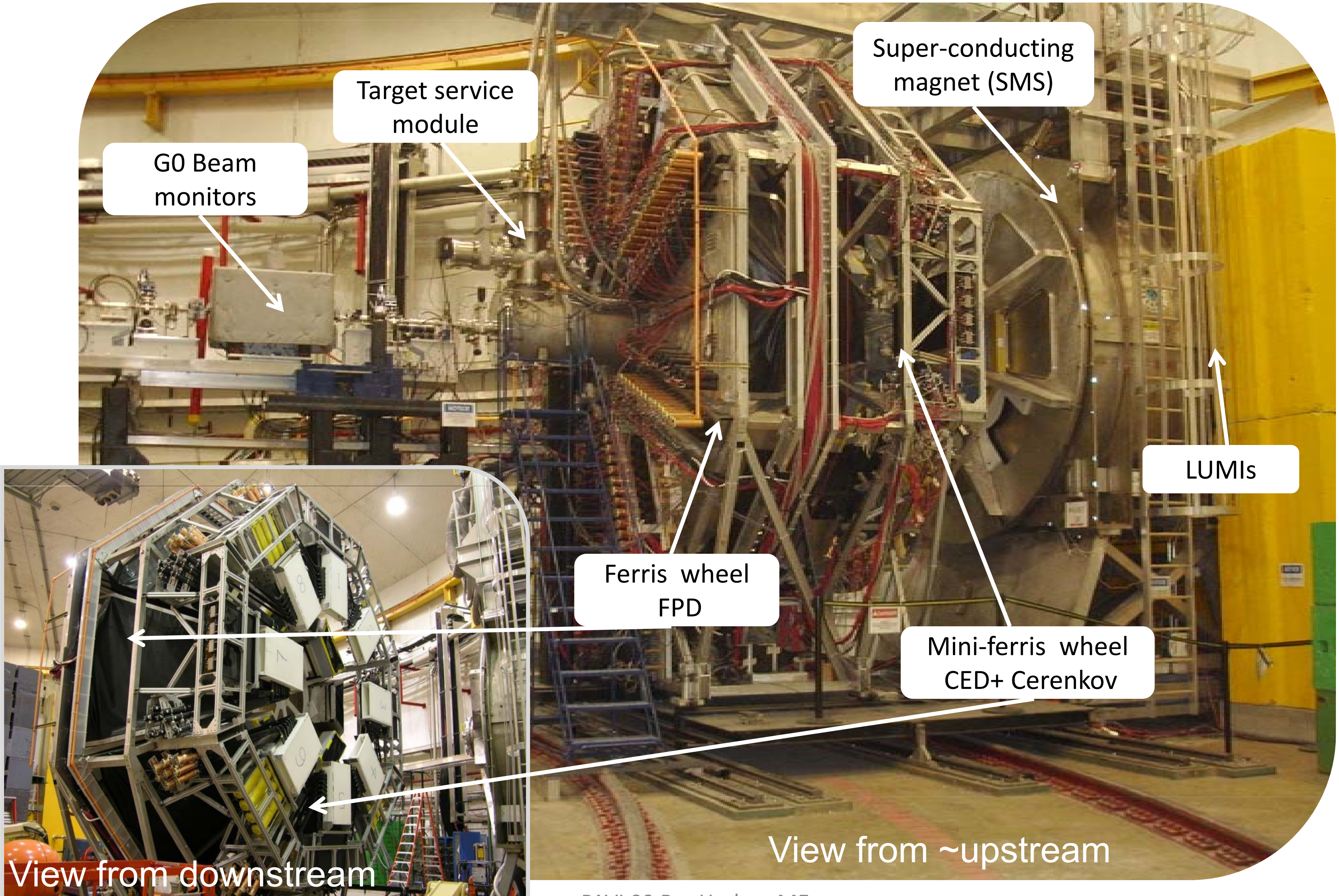
Transverse Asymmetries

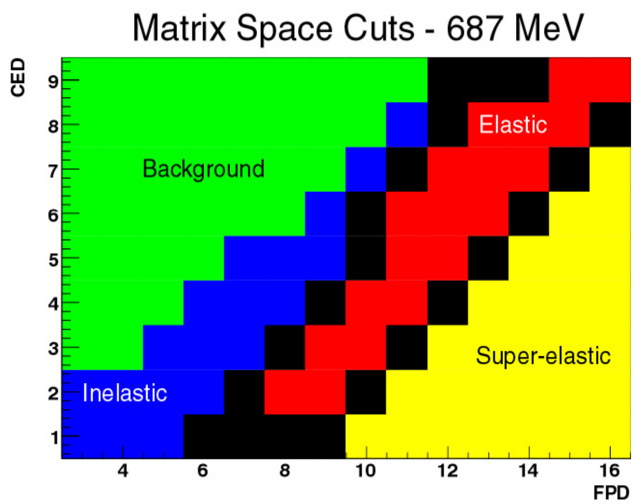
G0 Backward Angle

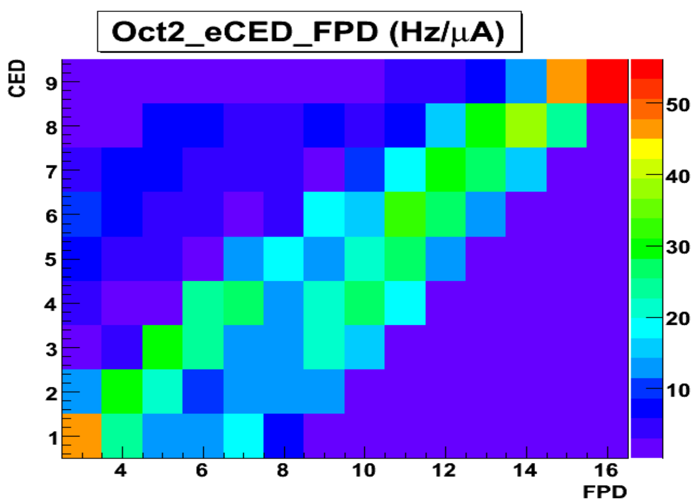
Juliette Mammei
Virginia Tech

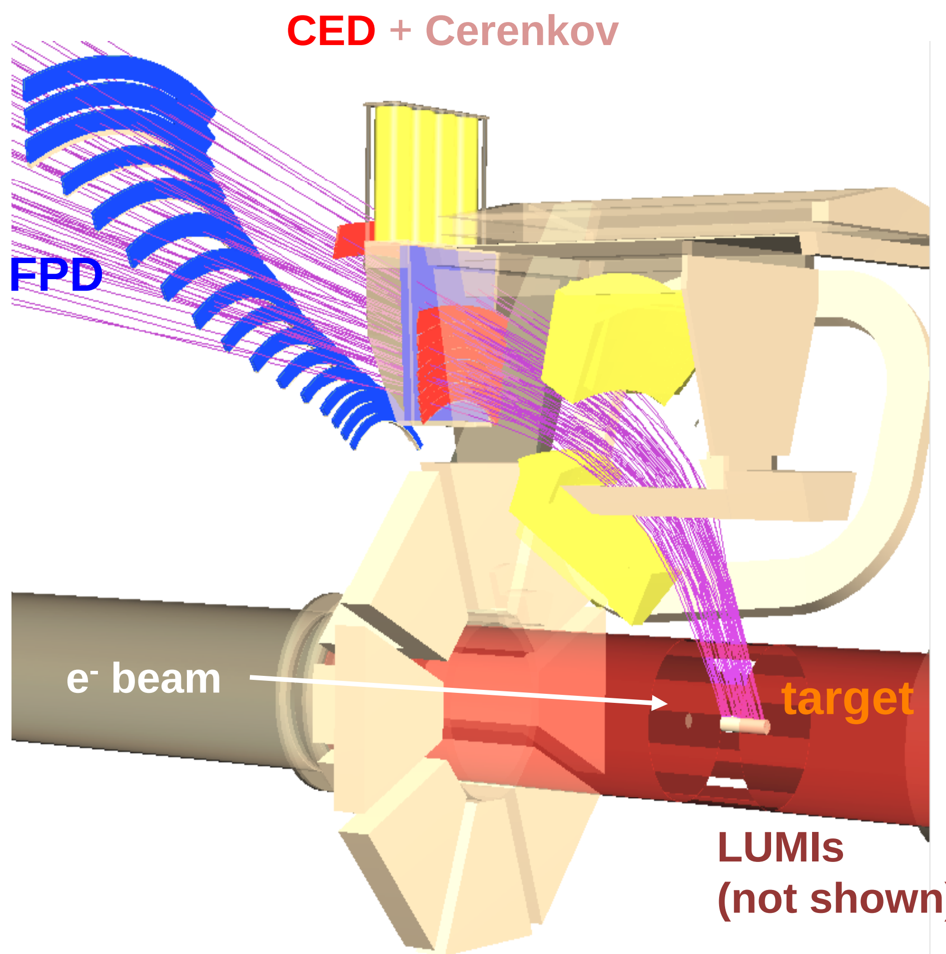
G0 Experiment



G0 Experiment

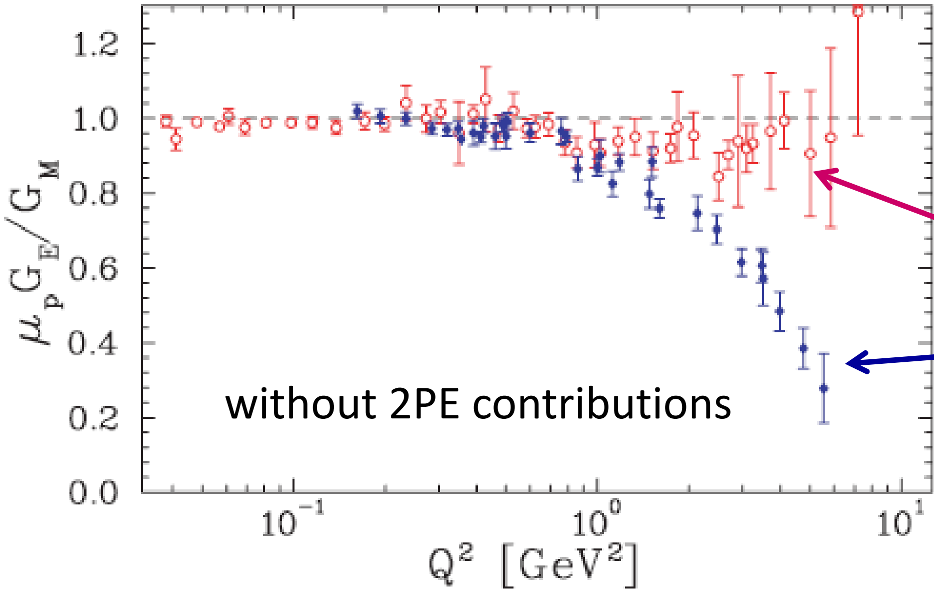


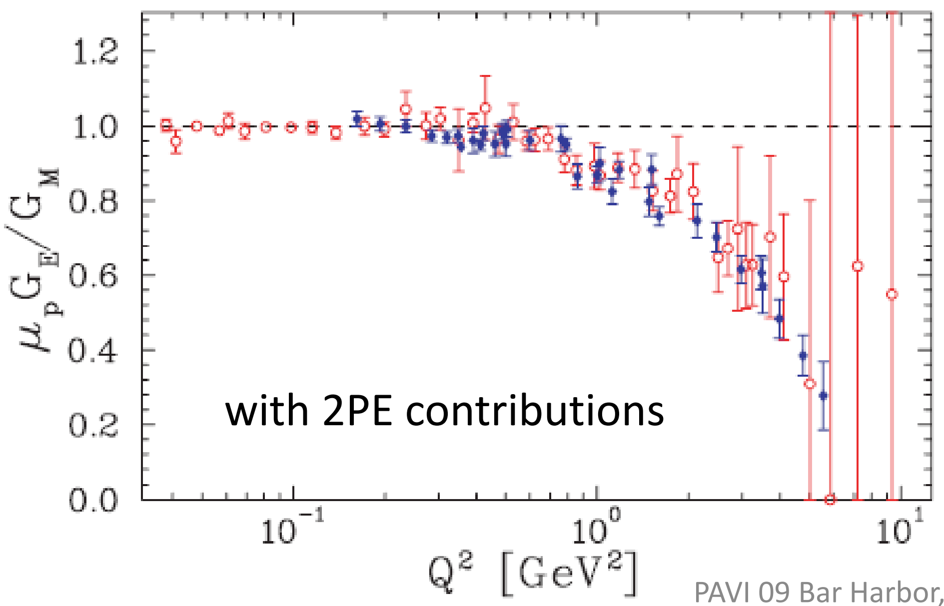




Motivation

Arrington, Melnitchouk, Tjon Phys. Rev. C 76, 035205 (2007)





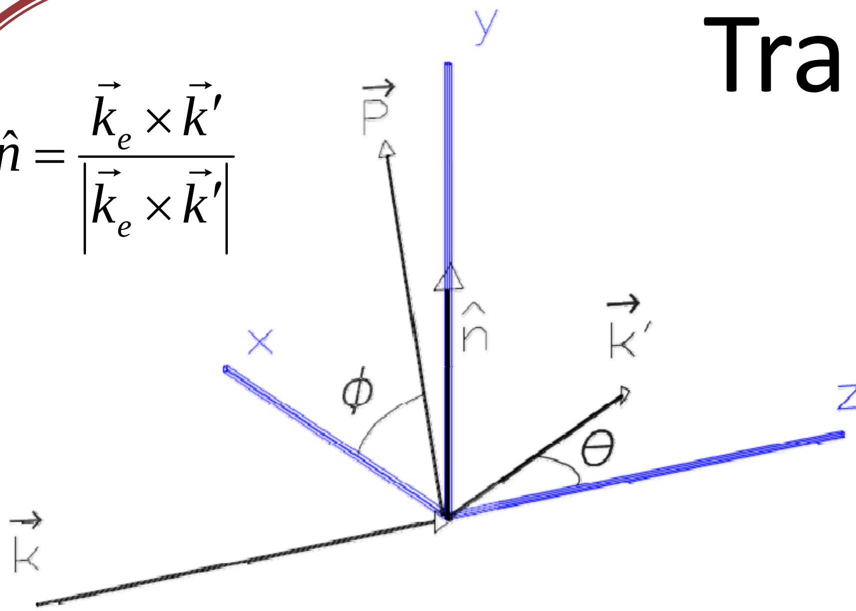
Inclusion of the real part of the 2γ exchange in the cross section may account for the difference between measurements of G_E/G_M from **unpolarized cross section** and **polarization transfer** measurements

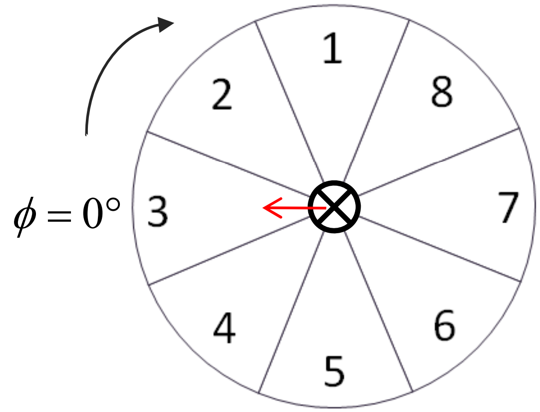
$$A_n \propto \frac{M_\gamma \, \mathrm{Im}\, M_{\gamma\gamma}}{\left|M_\gamma^2\right|}$$

Understanding the transverse asymmetries tests the theoretical framework that calculates the contribution of γZ and W^+W^- box diagrams that are important corrections to precision electroweak measurements

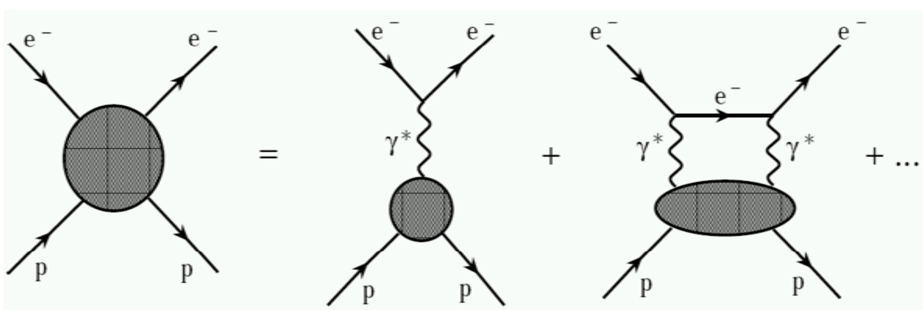
Transverse Asymmetry

$$\hat{n} = \frac{\vec{k}_e \times \vec{k}'}{\left|\vec{k}_e \times \vec{k}'\right|}$$



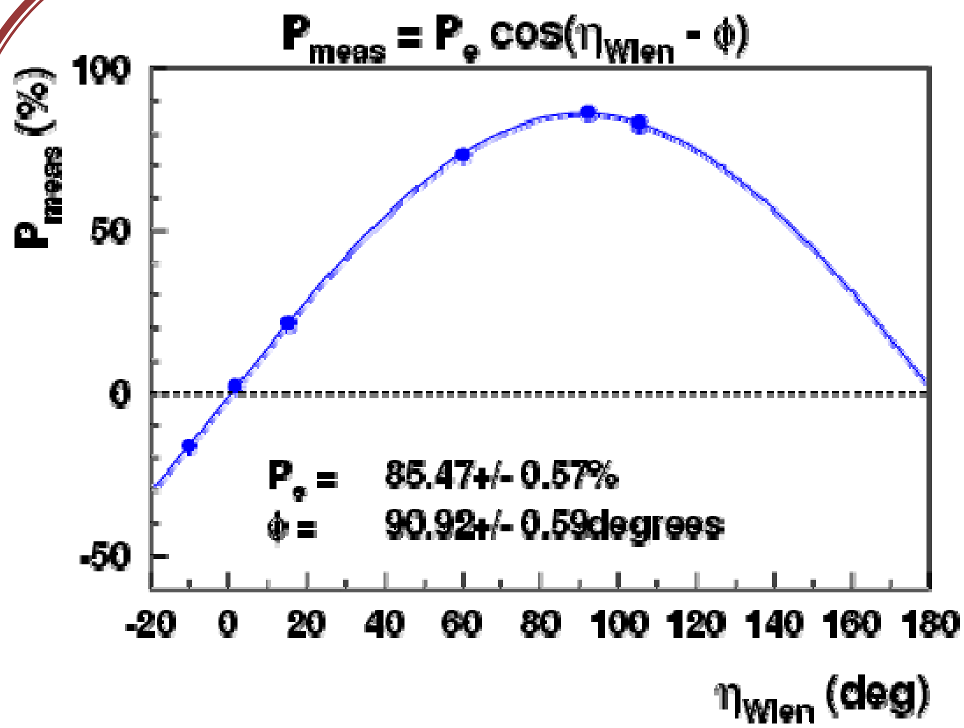


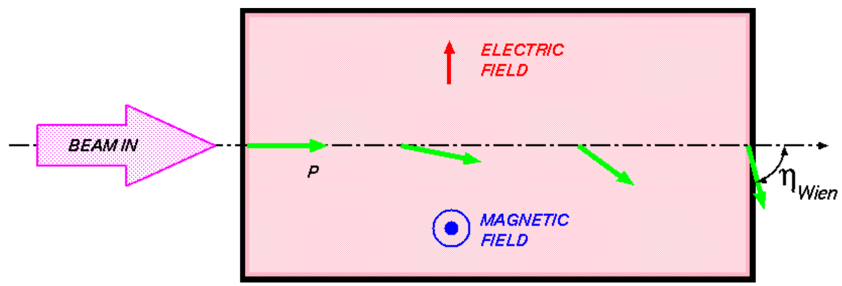
$$A_{\perp}^{m} = \frac{\sigma_{\uparrow} - \sigma_{\downarrow}}{\sigma_{\uparrow} + \sigma_{\downarrow}} = A_n \vec{p}_e \cdot \hat{n} = -A_n \sin(\phi + \phi_0)$$

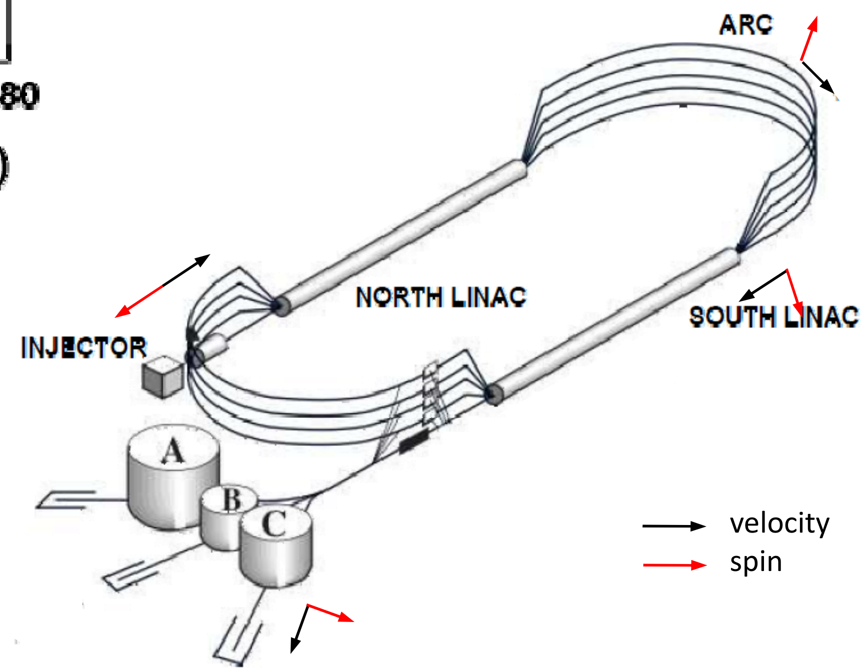


$$A_n \propto \frac{M_{\gamma} \operatorname{Im} M_{\gamma\gamma}}{\left|M_{\gamma}^{2}\right|}$$

Polarized Beam





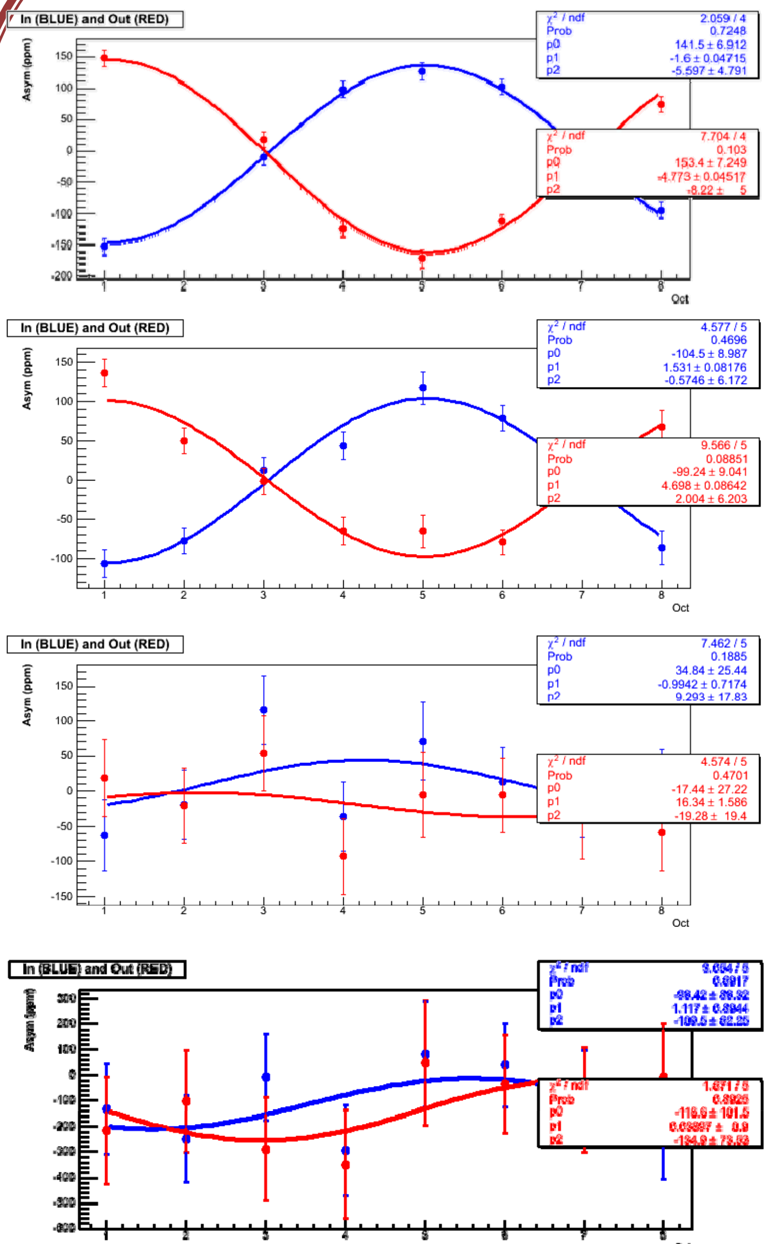


Moller polarimeter measurements give the longitudinal polarization in the hall as a function of wien angle

P_{meas}=0 means transversely polarized, in this case at ~0°

IHWP also reverses transverse P

Data Summary



Raw asymmetries

G0 Backward, Transverse:

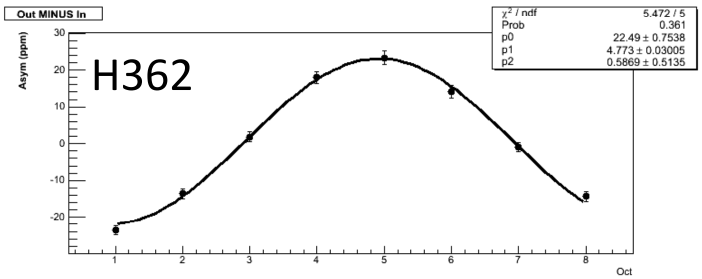
$\langle\theta_{lab}\rangle$ ~ 108° for all
a total of

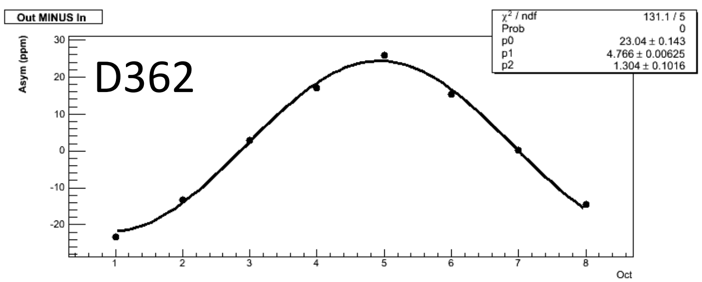
~50 hours of beam

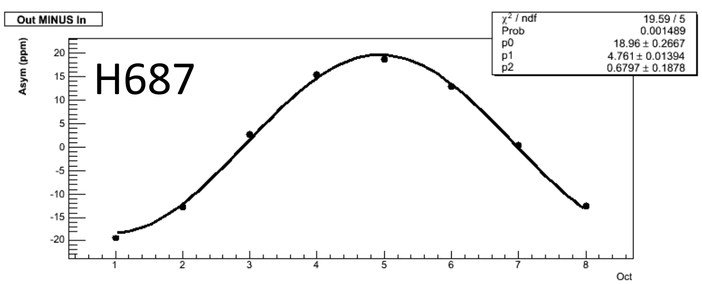
Target	Energy (MeV)	Q^2 (GeV^2/c^2)	Amount of Data C IN / C OUT
H	358.8 ± 0.5	0.222 ± 0.001	1.77 / 1.88
D	359.5 ± 0.7	0.219 ± 0.001	1.00 / 1.10
H	681.7 ± 0.9	0.626 ± 0.003	1.42 / 1.20
D	685.9 ± 0.9	0.630 ± 0.003	0.08 / 0.06

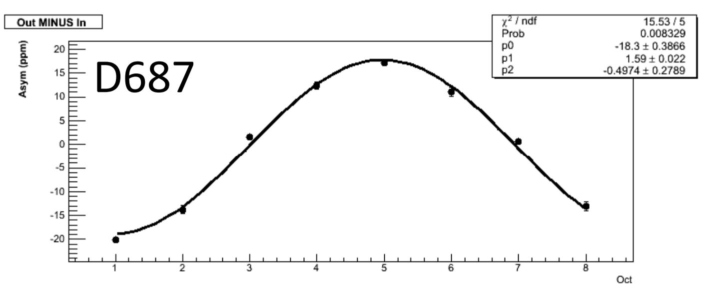
Free fits of the form $A\sin\left(\frac{2\pi}{8}(x-1)+\phi_0\right)+\Delta$

Luminosity Monitors/Phases









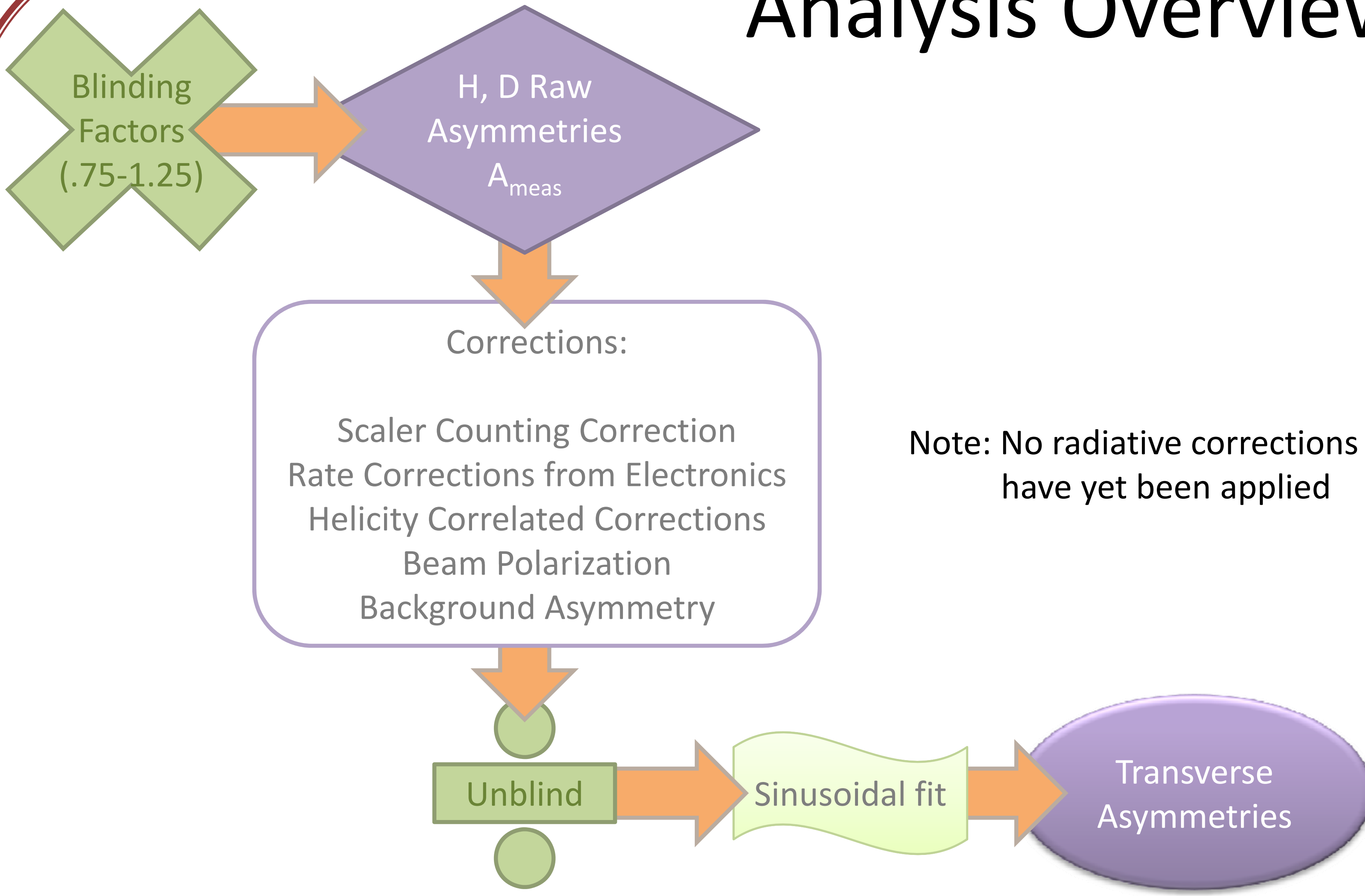
LUMI Phases

Dataset	ϕ_0
H362	-86.5° ± 1.7°
D362	-86.9° ± 0.4°
H687	-87.2° ± 0.8°
D687	-88.9° ± 1.3°

Detector Phases

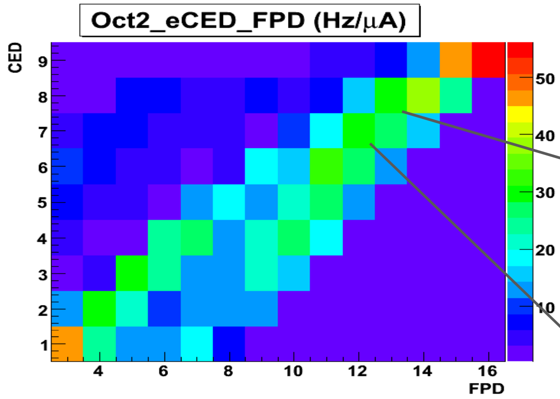
Dataset	ϕ_0
H362	-92.6° ± 1.9°
D362	-91.6 ° ± 3.4°
H687	-79.1° ± 68°
D687	-66.2 ° ± 63°

Analysis Overview



Note: No radiative corrections have yet been applied

Background Corrections

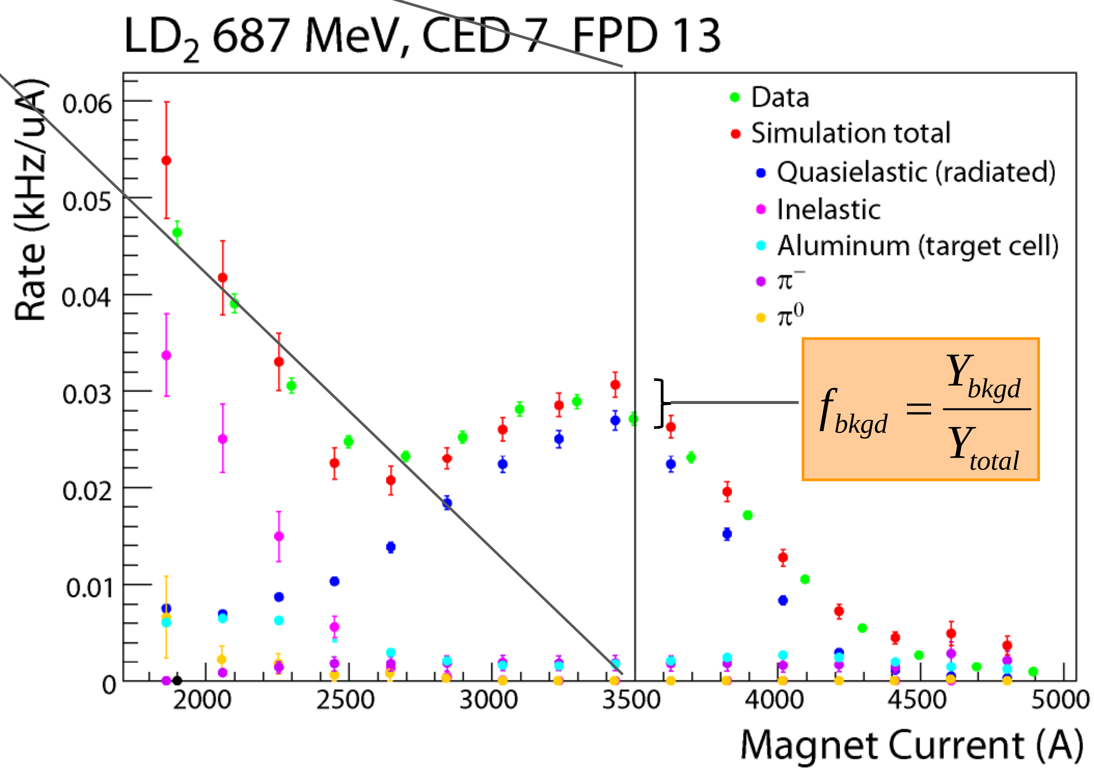


$$A = \frac{A_{meas} - f_{bkgd} A_{bkgd}}{1 - f_{bkgd}}$$

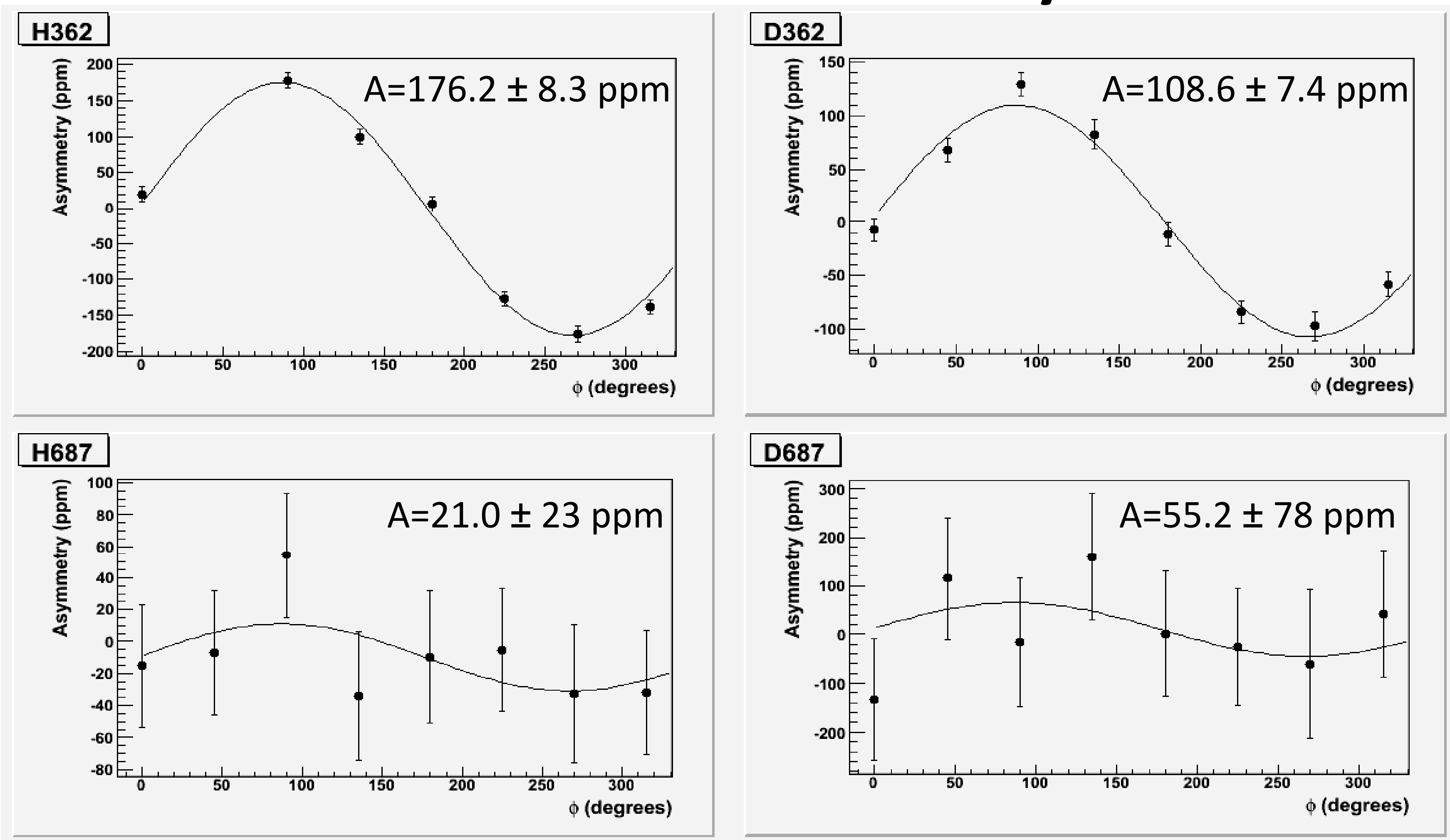
$$f_{Al} \sim 10-15\%$$

$$f_{other} \sim 1\%$$

$$f_{\pi^-} \sim 5\%$$



e^- Transverse Asymmetries



Fits of the form $A\sin(x+\phi_0)+\Delta$, where ϕ_0= 2.3°

Summary of Results

Dataset	Transverse Asymmetry $A_n \pm \sigma_{stat} \pm \sigma_{sys} \pm \sigma_{global}$ (ppm)	Change in asymmetry due to correction (%)			
		Scaler Counting	Rates from electronics	Linear Regression	Background Asymmetries
H362	-176.4 ± 5.7 ± 6.0 ± 2.8	<1%	2.9%	1.3%	4%
D362	-108.5 ± 6.7 ± 3.1 ± 1.7	< 1%	1.6%	< 1%	< 1%
H687	-21.0 ± 18 ± 15 ± 0.4	4%	4%	<1%	9%
D687	-55.2 ± 71 ± 32 ± 0.9	< 1%	28%	< 1%	10%

Backward angle data from other experiments:

SAMPLE(H): E=192 MeV, Q^2=.10 GeV^2, θ_{lab} =145º, A_n = -15.4+/- 5.4 ppm
Phys. Rev. **C63** 064001 (2001)

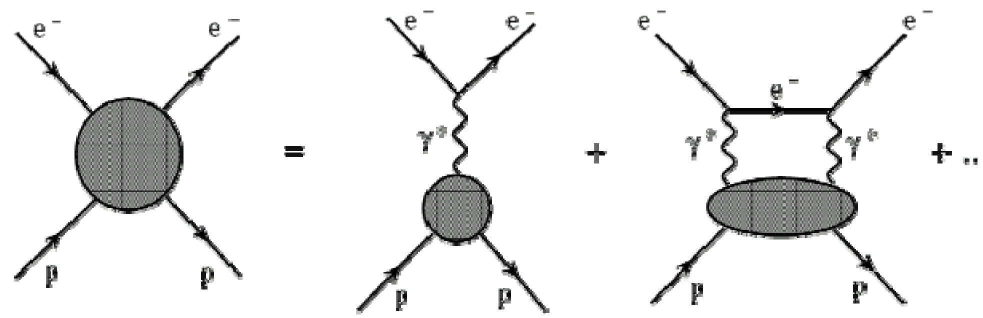
A4(H): E=315 MeV, Q^2=.23 GeV^2, θ_{lab} =145º, A_n = -87+/- 6 ppm
Eur. Phys. J. **A32** 497 (2007)

with more from A4 coming?

Theory Summary

The predictions of the asymmetry are sensitive to the physics of the intermediate hadronic state in the 2γ exchange amplitude

$$A_n \propto \frac{M_\gamma \, \mathrm{Im}\, M_{\gamma\gamma}}{\left|M_\gamma\right|^2}$$



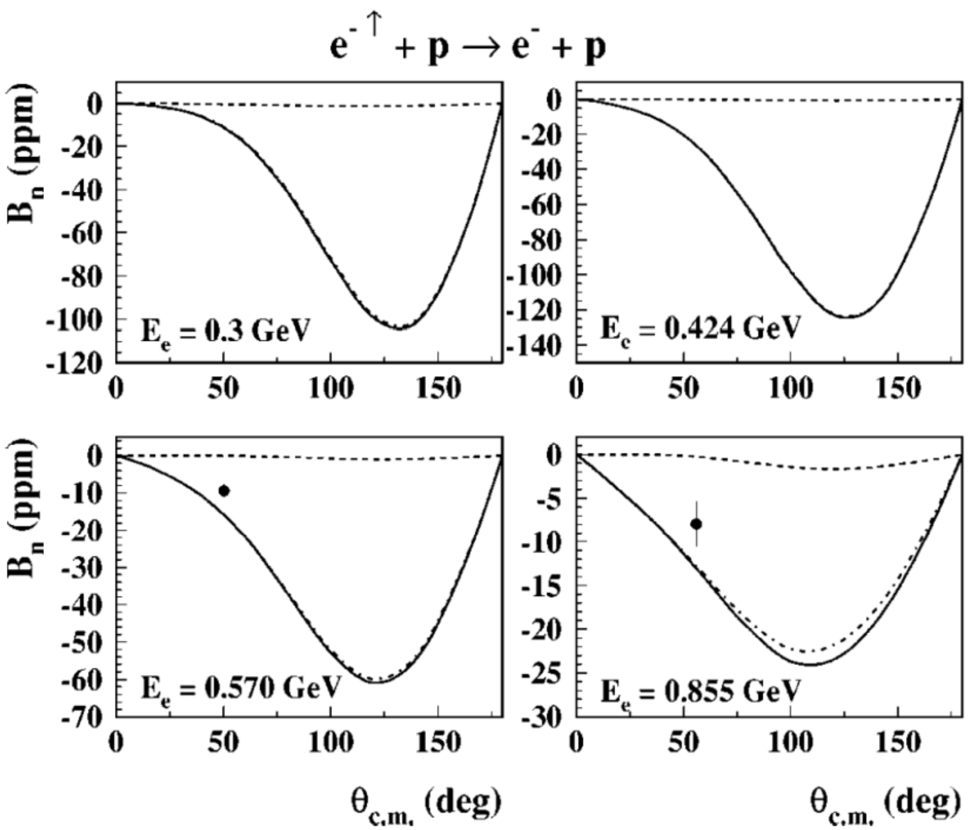
▪**Threshold region:** HBχPT
L. Diaconescu & M.J. Ramsey-Musolf, Phys. Rev. C70, 054003 (2004)

▪**Resonance region:** moderate energy
B. Pasquini & M. Vanderhaeghen, Phys. Rev. C70, 045206 (2004)

▪**High energy forward scattering region:** diffractive limit
Afanasev & Merenkov, Phys. Lett. B599, 48 (2004)
Gorchtein, Phys. Lett. B644, 322 (2007)

▪**Hard scattering region:** GPDs (Generalized Parton Distributions)
M. Gorchtein, P.A.M. Guichon, M. Vanderhaeghen, Nuc.Phys. A 741:234-248,2004

Resonance Region Estimates



Different hadronic intermediate states:

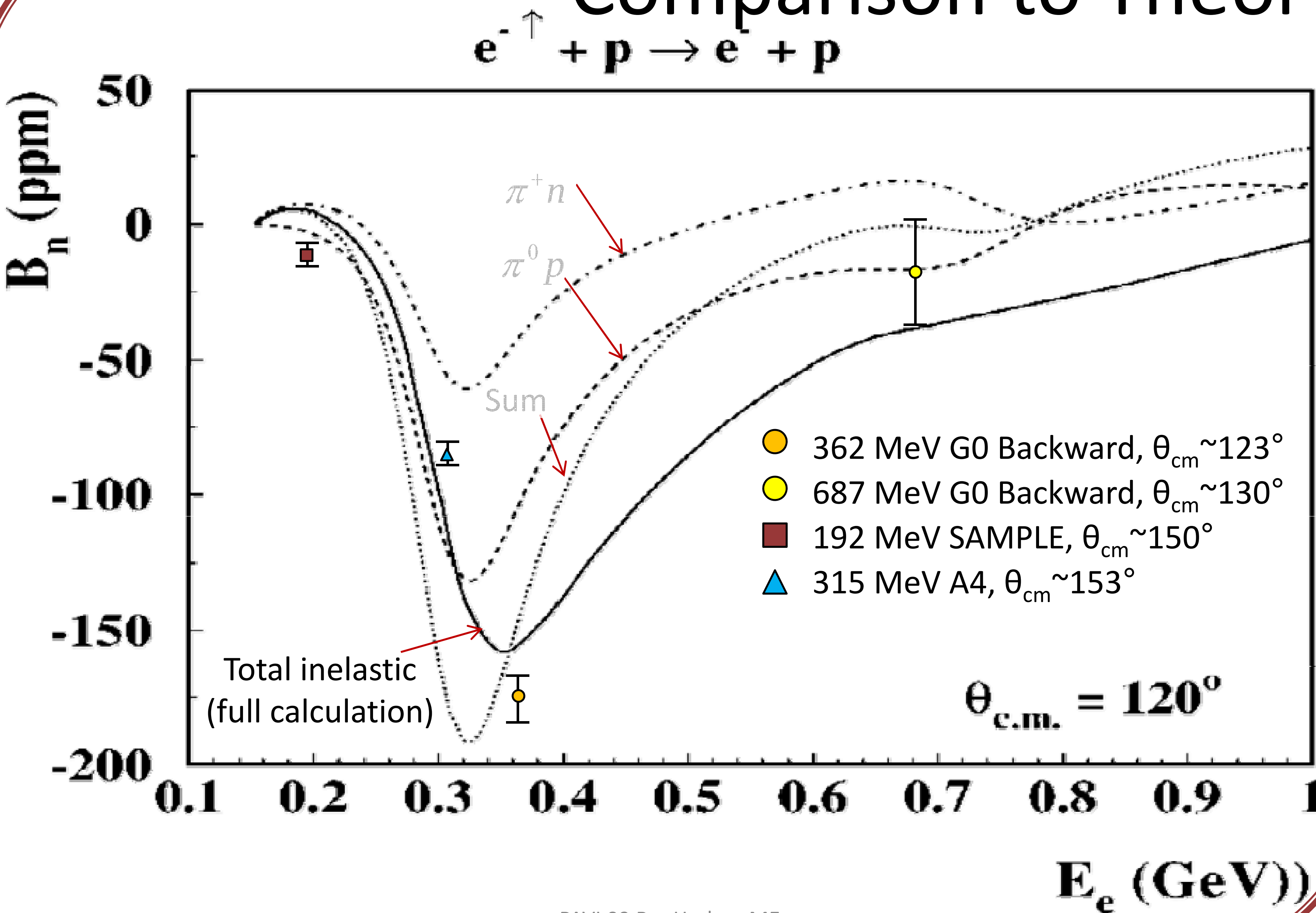
------------ N

-·-·-·-·- π N

———— Sum

"It will be interesting to check that for backward angles, the beam normal SSA indeed grows to the level of tens of ppm in the resonance region."

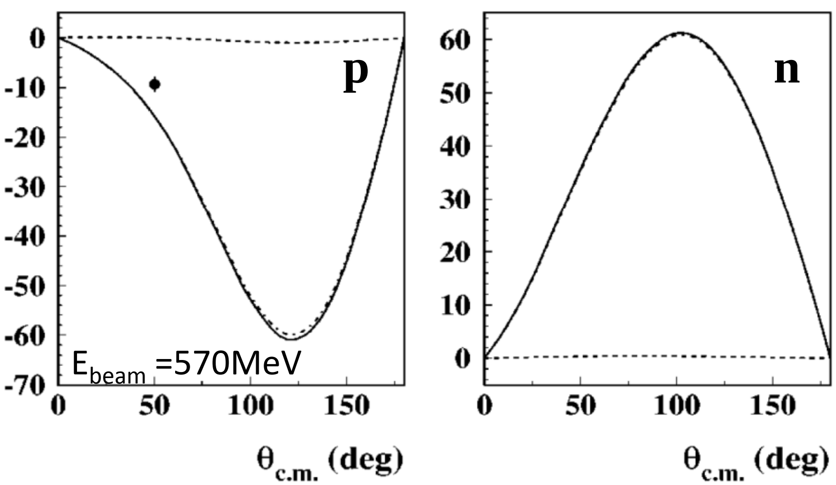
Comparison to Theory



hint of Transverse Asymmetries

for the neutron

362 MeV:	687 MeV:
σ_p = 23 μb/sr	σ_p = 2.6 μb/sr
σ_n = 8 μb/sr	σ_n = 1.1 μb/sr



$$A_p \approx -A_n$$

In the quasi-static approximation:

$$A_d = \frac{\sigma_p A_p + \sigma_n A_n}{\sigma_p + \sigma_n}$$

$$\approx A_p \frac{\sigma_p - \sigma_n}{\sigma_p + \sigma_n}$$

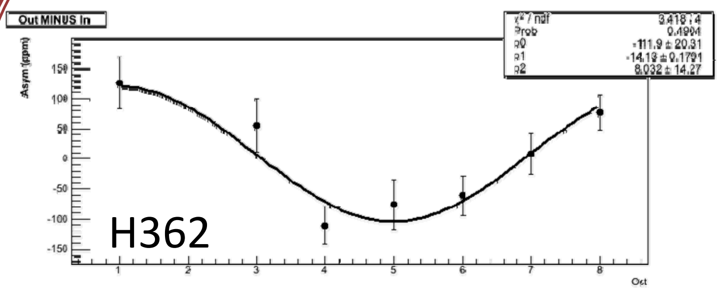
For 362MeV:

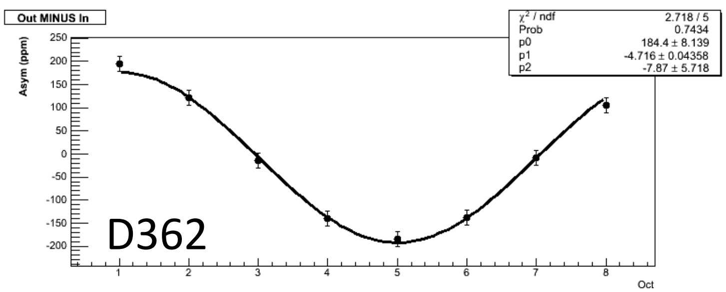
$$A_d = A_p \frac{23-8}{23+8} \approx 0.5 A_p$$

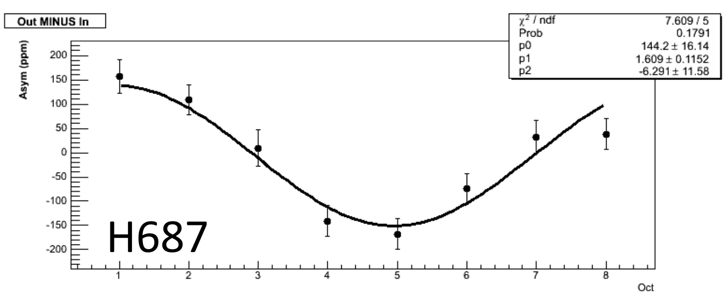
$$\frac{A_d}{A_p} = \frac{-108.5 \pm 8.7}{-176.4 \pm 7.6} \approx 0.6 \pm 0.1$$

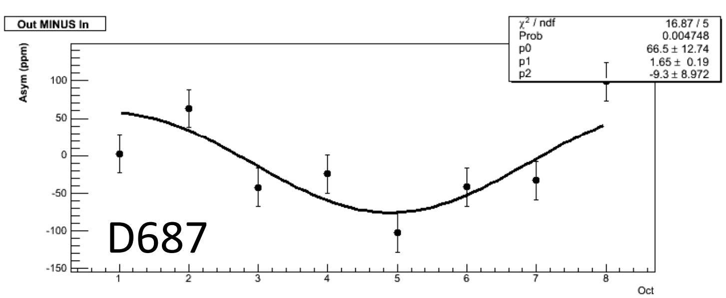
Pion Asymmetries

raw data









Dataset	Amplitude	ϕ_0
H362	-112 ± 20	-90° ± 2°
D362	-184 ± 8	-90° ± 2°
H687	-144± 16	-88° ± 7°
D687	-67 ± 13	-85° ± 11°

Note: there is no background asymmetry correction here; there may be very large electron contamination

errors are statistical

Trying to determine the theoretical implications – input is welcome!

The G^0 Collaboration

G^0 Spokesperson: Doug Beck (*UIUC*)

California Institute of Technology, Carnegie-Mellon University, College of William and Mary, Hendrix College, IPN Orsay, JLab, LPSC Grenoble, Louisiana Tech, New Mexico State University, Ohio University, TRIUMF, University of Illinois, University of Kentucky, University of Manitoba, University of Maryland, University of Winnipeg, Virginia Tech, Yerevan Physics Institute, University of Zagreb

Analysis Coordinator: Fatiha Benmokhtar (Carnegie-Mellon,*Maryland*)

Thesis Students:
Stephanie Bailey (*Ph.D. W&M, Jan '07, not shown*)
From left to right: Colleen Ellis (*Maryland*) , Alexandre Coppens (*Manitoba*),
Juliette Mammei (*VA Tech*), Carissa Capuano (*W&M*),
Mathew Muether (*Illinois*), Maud Versteegen (*LPSC*) , John Schaub (*NMSU*)

Backup Slides

Transverse Uncertainty

in Longitudinal Data

Dataset	Longitudinal Asymmetry $A \pm \sigma_{stat} \pm \sigma_{sys} \pm \sigma_{global}$ (ppm)	$\sigma_{transverse}$ (ppm)
H362	-11.0 ± 0.8 ± 0.3 ± 0.4	0.036 ± 0.002
D362	-16.5 ± 0.8 ± 0.4 ± 0.2	0.024 ± 0.002
H687	-44.8 ± 2.0 ± 0.8 ± 0.7	0.012 ± 0.014
D687	-54.0 ± 3.2 ± 1.9 ± 0.6	0.008 ± 0.008

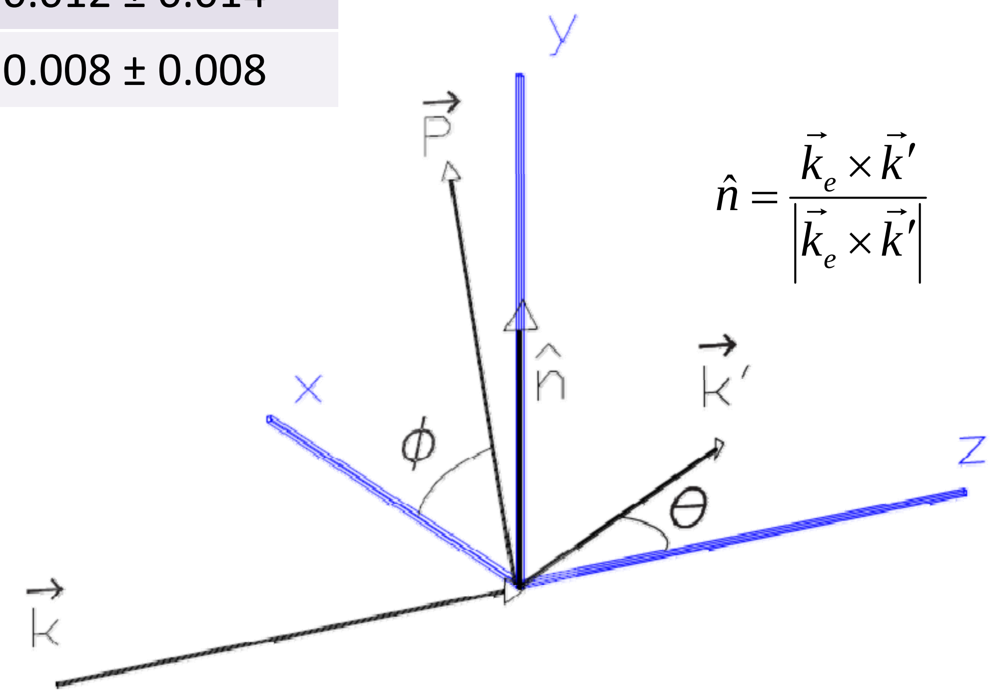
$$K_T = A_T \frac{P_T}{P} A_S$$

Upper estimate of detector asymmetry factor:

$$A_S \approx 1\%$$

If you assign all octant variation in yields to variation in central scattering angle

$$\hat{n} = \frac{\vec{k}_e \times \vec{k}'}{\left|\vec{k}_e \times \vec{k}'\right|}$$



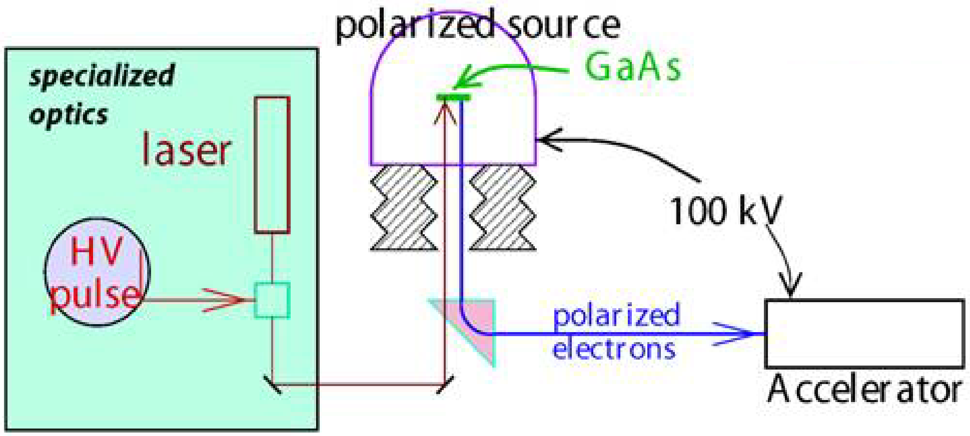
Polarized Electron Source

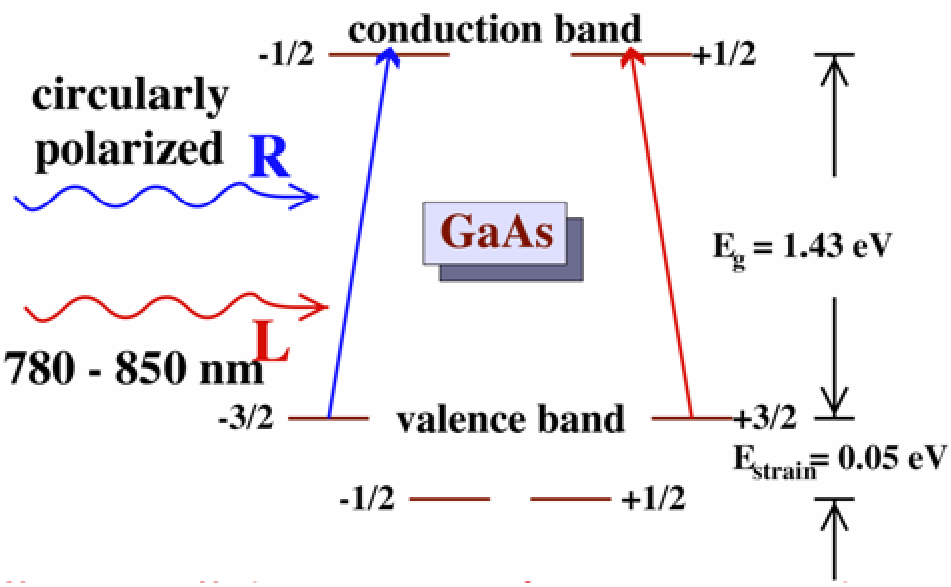
photoemission of electrons from GaAs

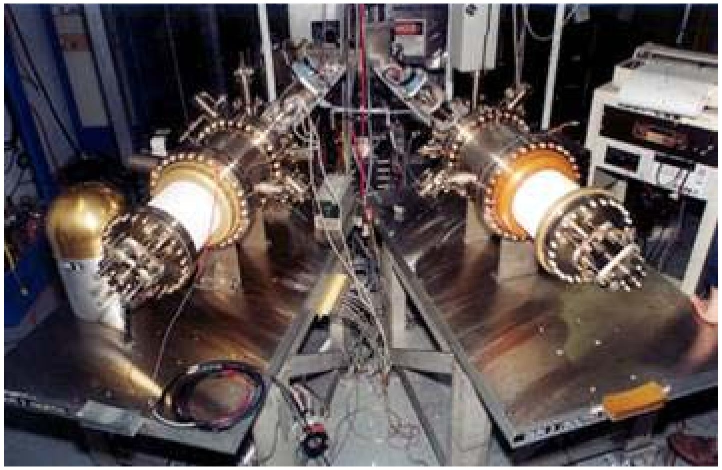
$\rightarrow$"Bulk" GaAs typical P_e ~ 37%
theoretical maximum - 50%

$\rightarrow$ "Strained" GaAs = typical P_e ~ 80%
theoretical maximum - 100%

"Figure of Merit" $\propto I P_e^2$



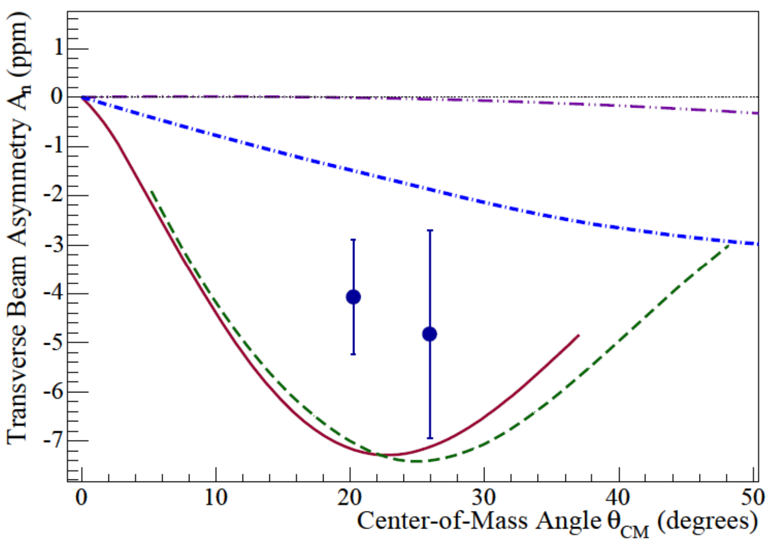


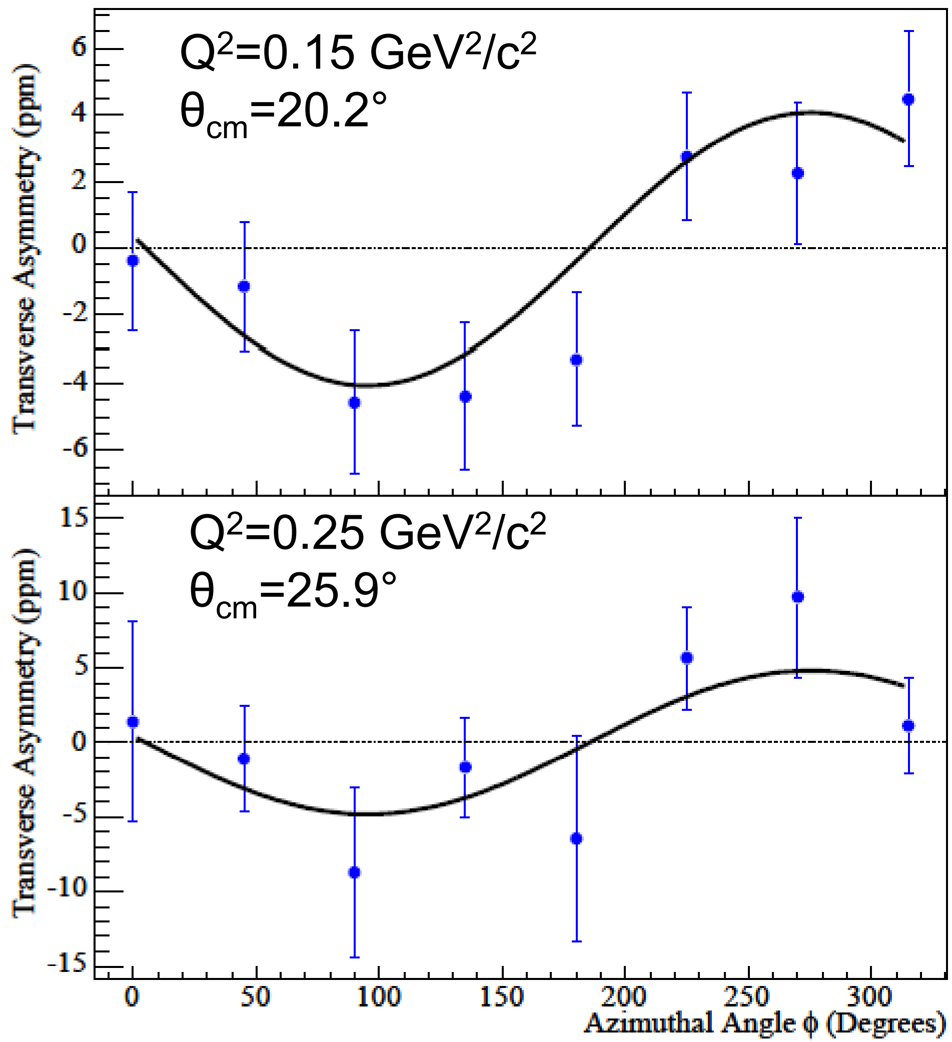


Forward Angle Transverse

Q^2 (GeV^2/c^2)	Transverse Asymmetry $A_n \pm \sigma_{stat} \pm \sigma_{sys}$ (ppm)
0.15	-4.06 ± 0.99 ± 0.63
0.25	-4.82 ± 1.87 ± 0.98

E_{beam} =3 GeV





Transverse Asymmetry

$$A_n = \eta \times \left\{ -\tau G_M \operatorname{Im}(\widetilde{F}_3 + \beta \widetilde{F}_5) - \operatorname{Im}(\widetilde{F}_4 + \beta \widetilde{F}_5) \right\} + \vartheta(\alpha^2)$$

$$\eta = \frac{2m_e}{Q^2} \frac{\sqrt{2\varepsilon(1-\varepsilon)}\sqrt{1+\tau^{-1}}}{(G_M^2 + \frac{\varepsilon}{\tau} G_E^2)} \qquad \tau = \frac{Q^2}{4M} \qquad \beta = \frac{1}{1+\tau} \frac{\nu}{M^2}$$

$$\varepsilon = \frac{\nu^2 - M^4 \tau(1+\tau)}{\nu^2 + M^4 \tau(1+\tau)}$$ - virtual photon polarization parameter

M - nucleon mass

$\widetilde{F}_i$ - contains intermediate hadronic state information