High Energy Neutral Pion Photoproduction

- R Gilman, B Wojtsekhowski et al.
- Continuation of E94-012 $\gamma p \rightarrow \pi^0 p$, using calorimeter like E99-114, $\gamma p \rightarrow \gamma p$

Physics motivation - GPDs

Some experimental details

Time request

Summary

http://www.jlab.org/~gilman/prop2005_v1.pdf

Physics Motivation I

- 1970s: Scaling of exclusive reaction cross sections explained by pQCD, hadron helicity conservation also predicted
- Late 1980s-1990s: Problems understanding magnitude of cross sections from pQCD
- Late 1990s-2000s: Realization handbag + GPDs might explain data

Physics Motivation II

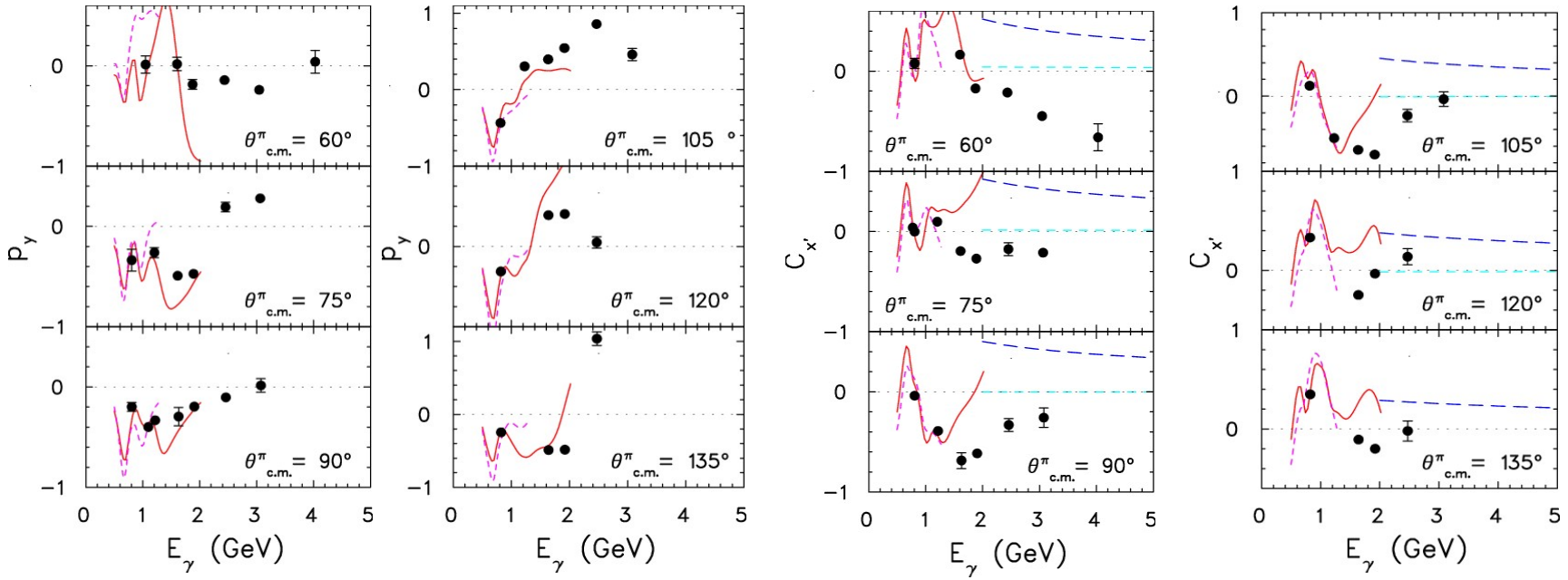
- Starting from the nucleon spin structure measurements, to G_E^p, A_1^n, … we have recognized that orbital angular momentum is important
- Data that constrains GPDs allows the orbital angular momentum to be evaluated: proton spin is ~$\frac{1}{4}$ quark spin, $\frac{1}{4}$ quark L, $\frac{1}{2}$ gluon spin

Physics Motivation III

- Need for DVCS+meson production known
- High energy pion photo-production allows GPDs to be investigated over a wide kinematic range... but we do not have the data that show the GPD/handbag mechanism applies
- This is the main goal of this proposal.
- We can also test other physical ideas: resonance contributions, Regge theory, ...

E94-012: Wijesooriya et al.

- Resonances dominate to E=3, W=2.55 GeV

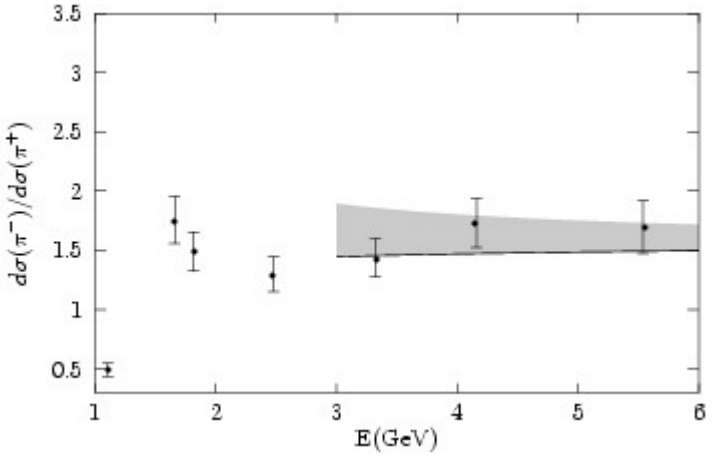


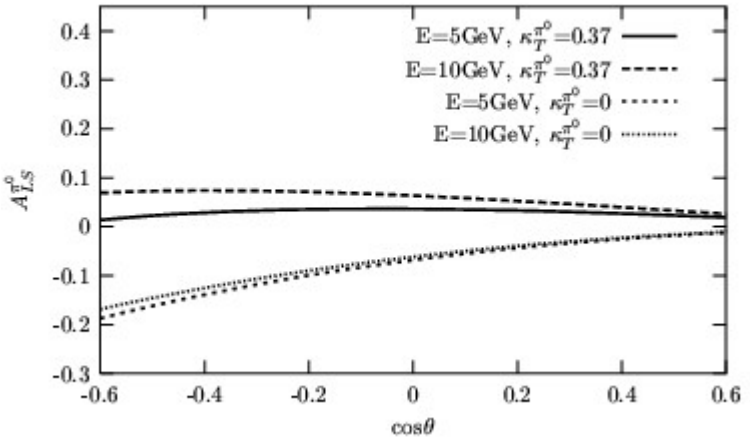
$K^+\Lambda^0$ Photoproduction

- Hall B data show that $K^+\Lambda^0$ photo-production, unlike the π^0p case, has very simple spin observables: the Λ^0 is polarized in the direction of the spin of the incident photon
- Unlike expectations from helicity conservation, polarization transfer to quark, or resonances... could this happen?

GPD Predictions

- Huang, Jakob, Kroll, Passek-Kumerički, EPJC 33, 91 (2004)





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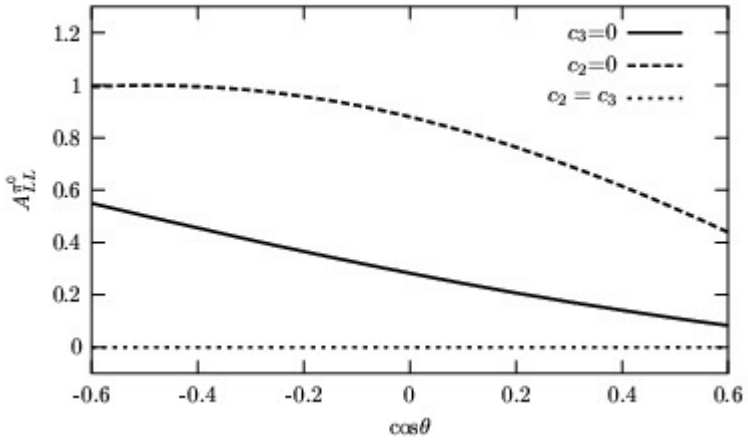
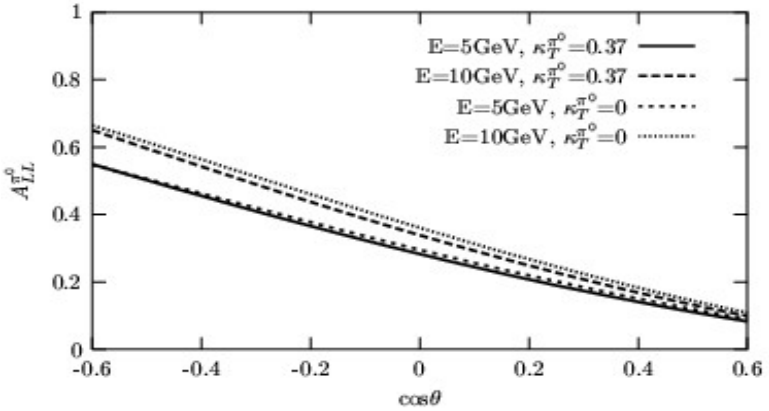


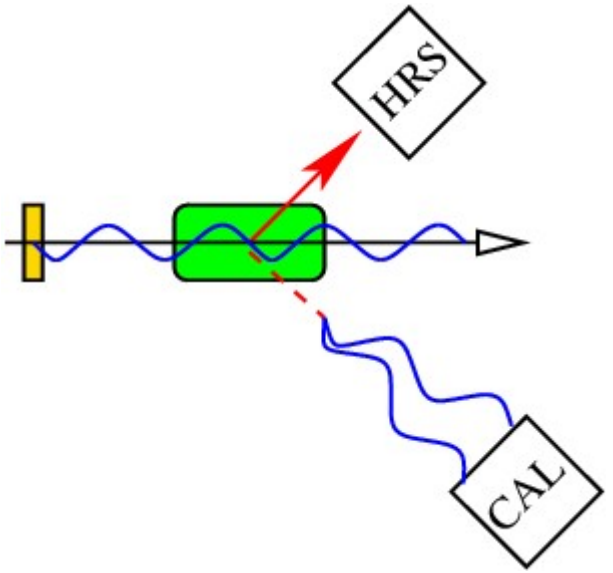


Motivation Summary

- $\gamma p \rightarrow \pi^0 p$ mechanism at high energy is not understood – there are only limited cross section data
- Smooth polarization behaviors can likely be explained by handbag/GPD mechanism
- Structures likely indicate important resonance contributions
- Could spin be in photon spin direction?

Experiment Overview

- 30 μA, ~5.5 GeV, h=0.8 polarized electrons
- 6% photon radiator
- 15 cm LH_2 target
- P into HRS with FPP
- $\pi^0 \rightarrow \gamma\gamma$ decay, BOTH photons detected in BIGCAL

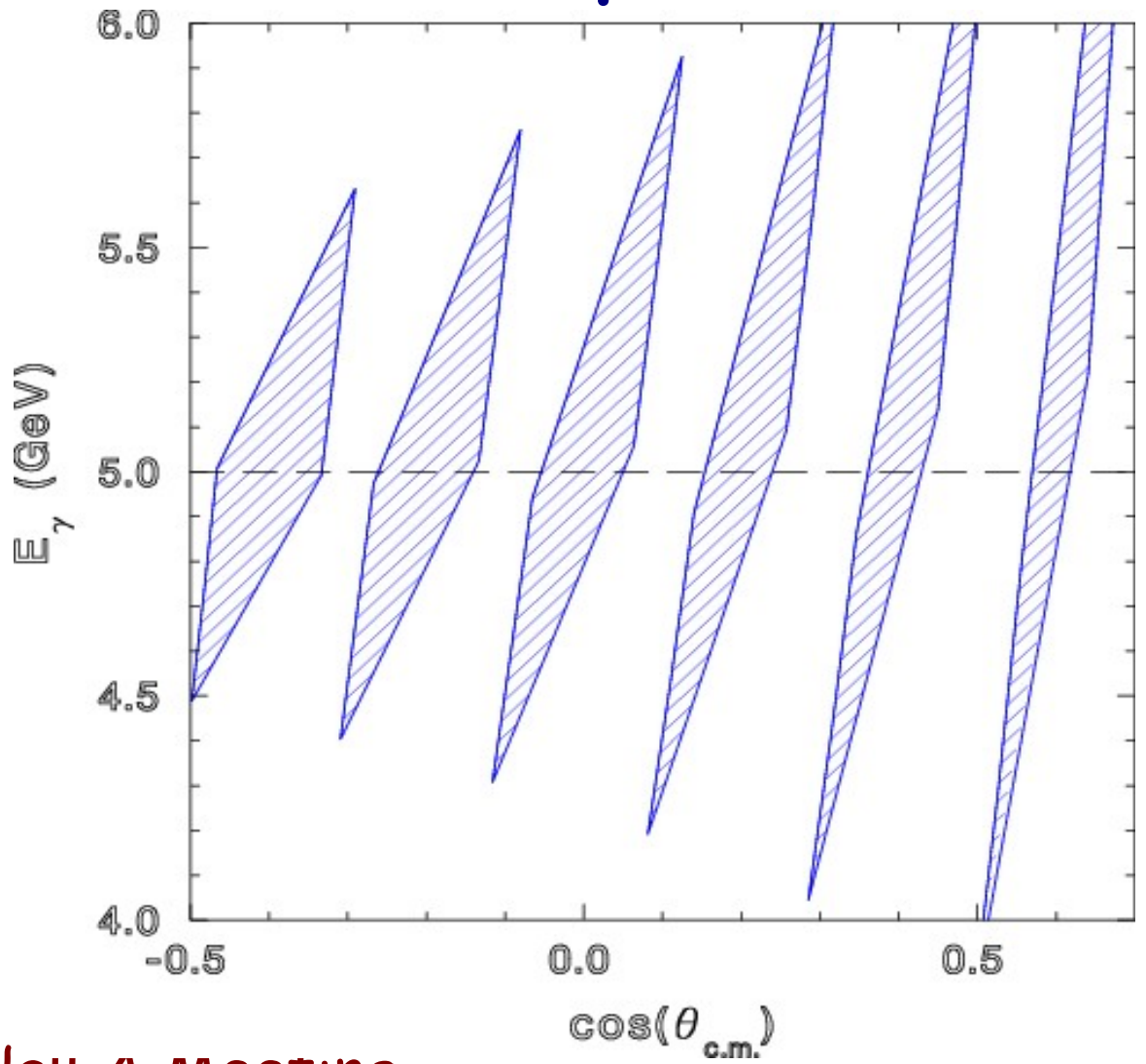


Kinematics: E=5 GeV, W=3.2 GeV

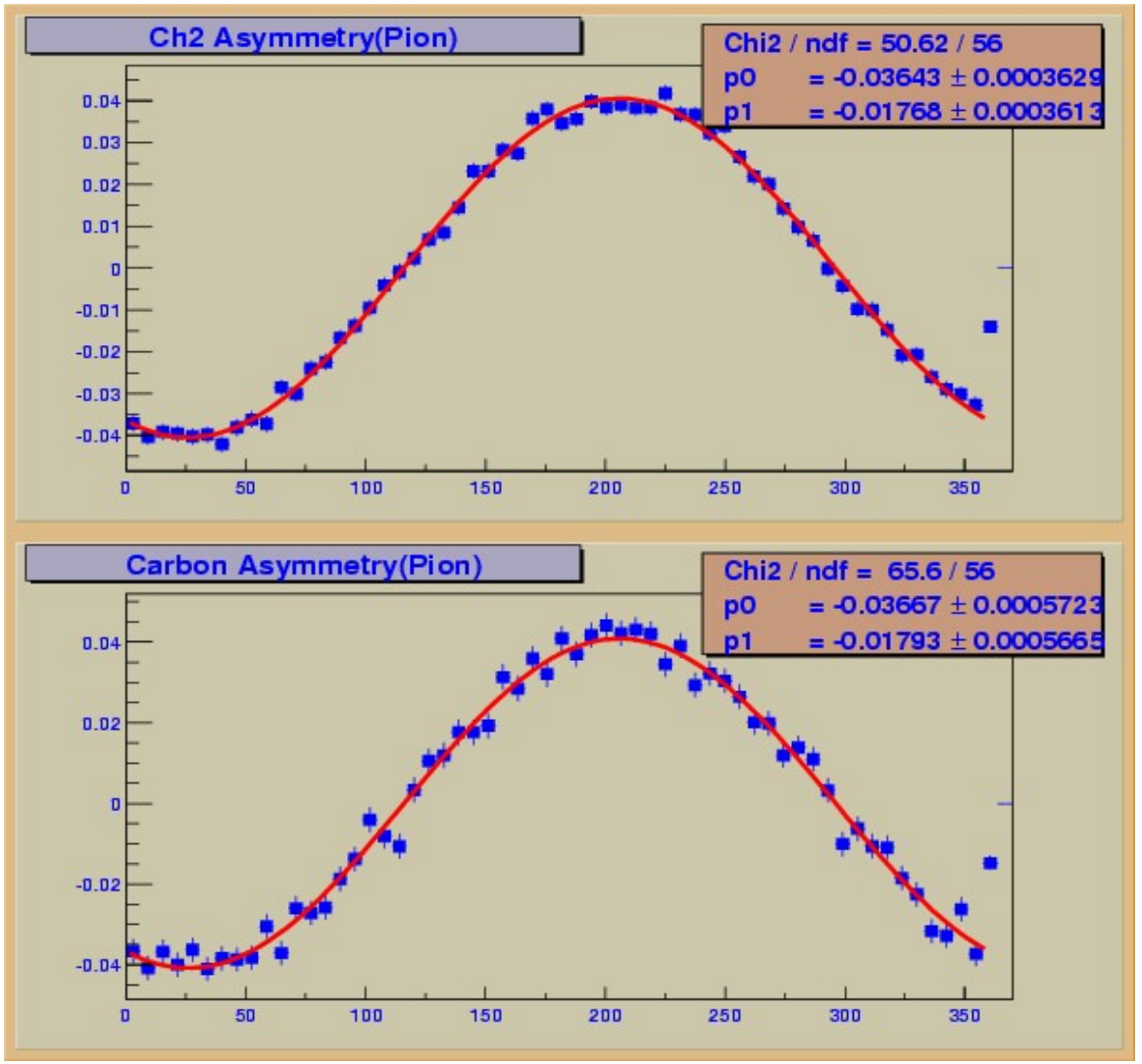
- Cover wide angle range with many steps

$\cos(\theta\pi^{cm})$	-0.40	-0.20	0.00	0.20	0.40	0.60
θ_π^{cm} (deg)	113.58	101.54	90.00	78.46	66.42	53.13
θ_π^{lab} (deg)	47.98	39.31	32.54	26.82	21.65	16.62
p_π^{lab} (GeV)	1.80	2.26	2.72	3.17	3.63	4.09
θ_p^{lab} (deg)	19.44	23.76	28.33	33.43	39.46	47.13
p_p^{lab} (GeV)	4.02	3.55	3.07	2.60	2.11	1.59
t (GeV^2)	-5.99	-5.13	-4.28	-3.42	-2.57	-1.71
u (GeV^2)	-2.49	-3.35	-4.21	-5.06	-5.92	-6.77
p_T (GeV)	1.34	1.43	1.46	1.43	1.34	1.17

Acceptance

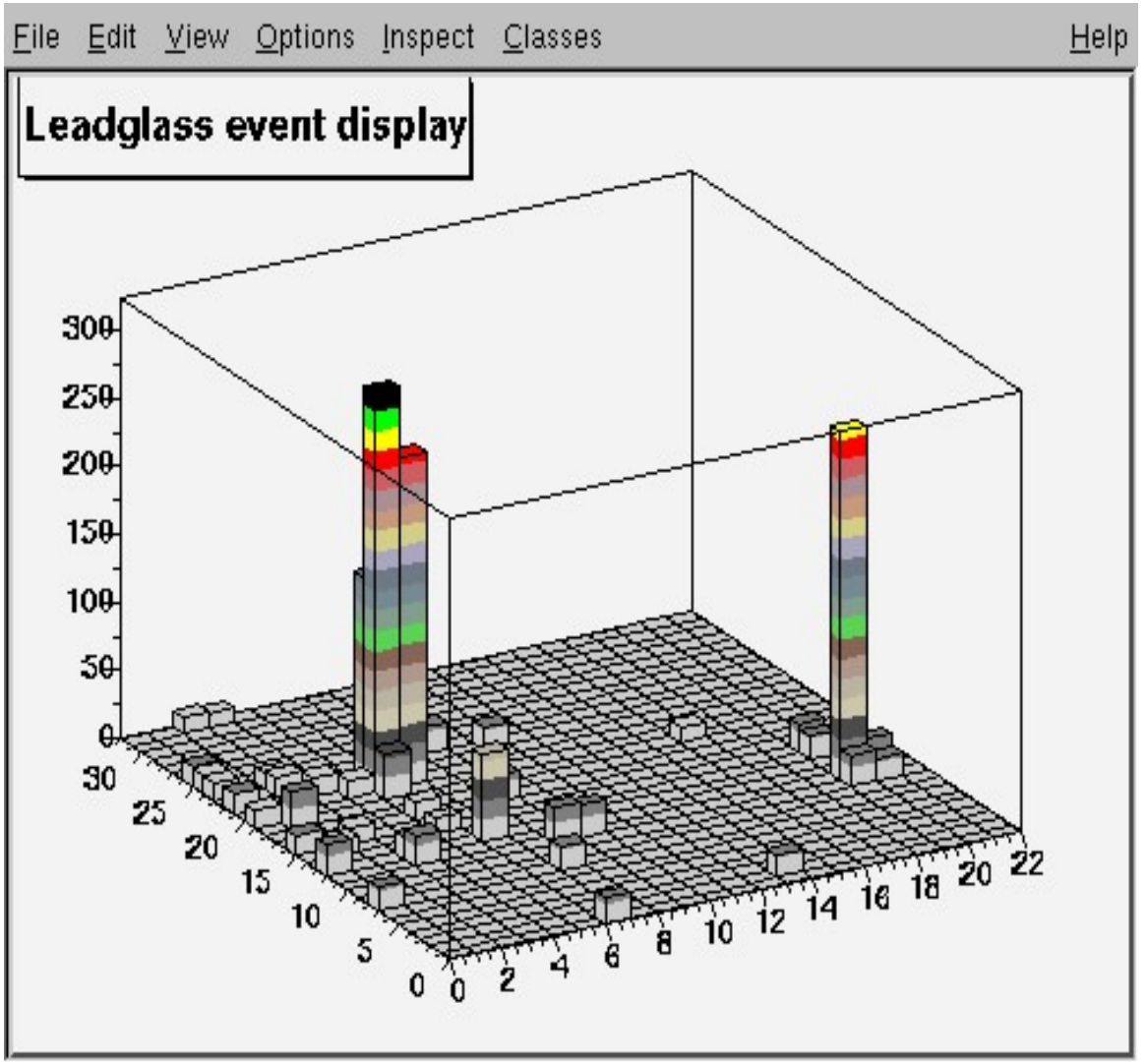


Dual Analyzer FPP



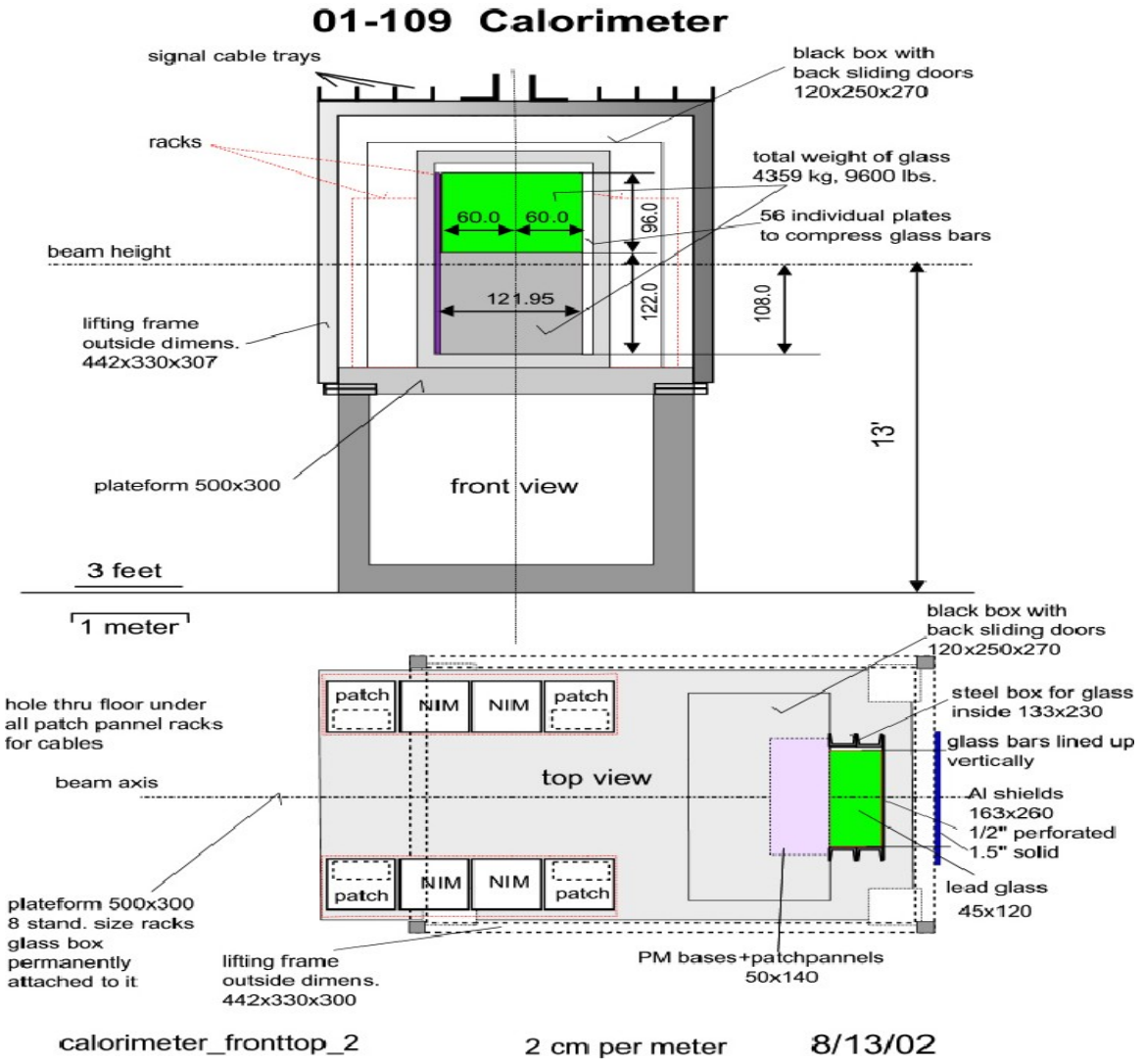
Calorimeter for $\pi^0 \rightarrow \gamma\gamma$ detection

- $\Delta E = 6\%/\sqrt{E}$
- ΔE=1-3 mr
- Δm_π = ~15 MeV
- 1 GeV π into RCS calorimeter



BIGCAL for $\pi^0 \rightarrow \gamma\gamma$ detection

- 1744 blocks
- 1.2m x 2.2m
- ~$\frac{1}{2}$ from RCS cal
- Hall A+C, G_e^p -III first



Calorimeter Settings: E=5 GeV, W=3.2 GeV

$\cos(\theta_\pi^{cm})$	-0.40	-0.20	0.00	0.20	0.40	0.60
θ_π^{lab} (deg)	47.98	39.31	32.54	26.82	21.65	16.62
p_π^{lab} (GeV)	1.80	2.26	2.72	3.17	3.63	4.09
θ_π^{lab} range (deg)	12.50	10.30	8.80	7.80	7.10	6.40
ϕ_π^{lab} range (deg)	15.50	11.50	8.90	7.00	5.70	4.60
$D_{h\text{-match}}$ (m)	2.70	3.30	3.87	4.38	4.82	5.35
$D_{v\text{-match}}$ (m)	3.97	5.41	7.02	8.96	11.02	13.67
$D_{planned}$ (m)	3.00	4.00	5.00	6.00	7.00	8.00

Backgrounds to $\gamma p \rightarrow \pi^0 p$

- Elastic ep (near endpoint)
  - One cluster with $E=E_\pi$ gives 99% ep
  - Use to calibrate FPP, calo E and Θ
- RCS: like ep, but small cross section
- Endcaps: remove by target cuts + coincidence
- Randoms: do not reconstruct m_π
- Heavier mesons: miss two γ's

Time request

$\cos(\theta_{\pi cm})$	-0.40	-0.20	0.00	0.20	0.40	0.60
$d\sigma/dt$ (nb/GeV^2)	0.50	0.50	0.50	0.60	1.00	2.10
Rate (Hz)	3.50	2.50	2.10	2.00	2.20	3.00
Time (days)	5.00	4.00	4.00	4.00	3.00	2.00
Δp_y^{lab}	0.03	0.06	0.22	0.07	0.03	0.02
$\Delta C_{x'}^{lab}$	0.04	0.05	0.05	0.05	0.03	0.02
$\Delta C_{z'}^{lab}$	0.15	0.07	0.05	0.06	0.11	0.08
Spin rotation	19.50	23.80	28.40	33.50	39.60	47.30

- Cross sections from Shupe et al.
- Estimates consistent with E94-012 experience, adjusted for beam energy, background reduction, ...

Summary

- Data goal: obtain systematic set of cross section and recoil polarization data for E_γ ~ 5 GeV
- Physics goal: test handbag/GPD predictions, vs. resonances, vs. ...
- Time request: 22 days
- Collaboration: experienced
- Resources: equipment exists, installation needed

Extras

- Planned for 100 MeV bin around 5 GeV – will obtain energy dependence as acceptance about 10 times larger
- Kinematically complete final state allows novel attempt to determine Σ, $O_{x'}$, $O_{z'}$ from reconstruction of photon azimuthal angle – Monte Carlos promising, but no experience

Observables

- We measure:

Observable	Amplitudes
Cross section	$N^2+S_1^2+S_2^2+D^2$
σPy	2Im(S2N*-S1D*)
$\sigma Cx'$	-2Re(S2N+S1D)
$\sigma Cz'$	1.0
$\sigma\Sigma$	1.0
$\sigma Ox'$	0.7
$\sigma Oz'$	