Measurement of p(e,e'p)π^0 near Threshold: a Test of Chiral Perturbation

Blaine Norum
University of Virginia

(for the JLAB Hall A and BigBite Collaborations)

Present World Data

Facility	Q^2 [GeV/c]^2	ΔW [MeV]	ϕ_{cm}	Reference
MAMI-B	0.0	0–110	N.A.	Fuchs 96
Saskatoon	0.0	3–20	N.A.	Bergstrom 96
NIKHEF	0.04, 0.1	0–2.5	0	Welch 92
NIKHEF	0.1	1–14	0, 180	Brink 97
MAMI-B	0.1	≤ 4	0, 180	Distler 98
MAMI-B	0.05	≤ 4	0, 180	Merkel 00

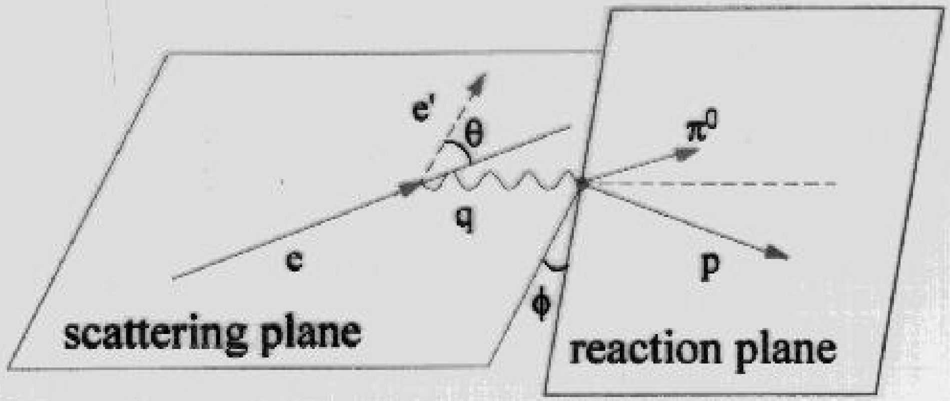
Jefferson Lab Proposal

Facility	Q^2 [GeV/c]^2	ΔW [MeV]	ϕ_{cm}	Reference
Hall-A	~~0.02*–0.22~~ 0.04–0.14	0–20	0-360	P01-014

Chiral Perturbation theory (ChPT)

- An important low energy QCD theory with widespread application
- Neutral pion electromagnetic production is particularly sensitive to ChPT
- $d\sigma/d\omega \sim |\text{Amplitudes (S-wave + P-wave} + \ldots|^2)$
- Amplitudes ~ Trees + Loops + LEC's
- Determine LEC's from experiment and predict evolution with W and Q.
- Widespread disagreements between theory and experiment should be resolved

Formalism



$$\frac{d\sigma}{d\Omega_f d\varepsilon_f d\Omega_\pi^*} = \Gamma\left(\sigma_T + \varepsilon_L \sigma_L + \sqrt{2\varepsilon_L(1+\varepsilon)}\sigma_{TL}\cos\phi_\pi^* + \varepsilon\sigma_{TT}\cos 2\phi_\pi^*\right)$$

$\sigma_T + \varepsilon_L \sigma_L$	~	$A + B\cos\theta_\pi^* + C\cos^2\theta_\pi^*$
σ_{TL}	~	$D\sin\theta_\pi^* + E\sin\theta_\pi^*\cos\theta_\pi^*$
σ_{TT}	~	$F\sin^2\theta_\pi^*$

Present Status of ChPT predictions of π^0 production near threshold

Consistencies

- E_{0+} amplitude (S- wave) from photoproduction data ($Q^2 = 0.0$) (SAL, MAMI, TAPS) is consistent with ChPT.
- E_{0+} amplitude from electroproduction data (NIKHEF, MAMI) at $Q^2 = 0.05$ and 0.1 $[GeV/c]^2$ is consistent with ChPT (20% level).

Discrepancies

Electroproduction ($Q^2 = 0.05$ and 0.10 $[GeV/c]^2$)

- Evolution of $\sigma_T + \varepsilon_L \sigma_L$, σ_{TL}, and σ_{TT} with Q^2 and W is inconsistent with Mainz data (L_{0+} and P-waves).
- S-wave cross section data from NIKHEF and Mainz is also inconsistent in the same range (L_{0+} and P-wave correction).
- S-wave cross section for deuterium is 10 times smaller than ChPT prediction (L_{0+}).

"Therefore, to clarify this, it is absolutely mandatory to have more *precise* data in the threshold region and on a *much finer* grid of photon virtualities." U.G. Meissner

Kinematics

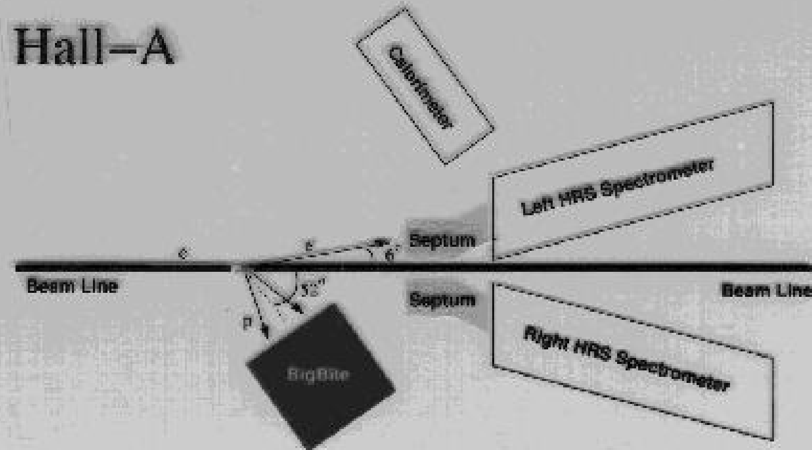
Setting Number	E [MeV]	Q^2 [MeV/c]2	W [MeV]	P_p [MeV/c]	Θ_p [degrees]
1	2400	0.04 – 0.08	1074	215 – 275	45 – 54
2	3200	0.07 – 0.14	1074	270 – 340	50 – 57
3	4000	0.11 – 0.22	1074	325 – 430	55 - 59

Setting Number	Beam E [MeV]	HRS E′ [MeV]	HRS Θ_e [degrees]	BigBite P_p [MeV/c]	BigBite Θ_p [degrees]	Beam Time [hours]
1	2400	2222	6.0	245	49.5	100
2	3200	2996	6.0	305	53.5	100
3	4000	3769	6.0	378	57.0	100

Setting Numbers
1 and 2 approved, but not 3

Jefferson Lab

Hall–A



Beam
- High Energy CW Electron Beam

Spectrometers (electron)
- Septum Magnets
- High Resolution

Target
- 10 cm Liquid Hydrogen
- 10 μm Havar Foil

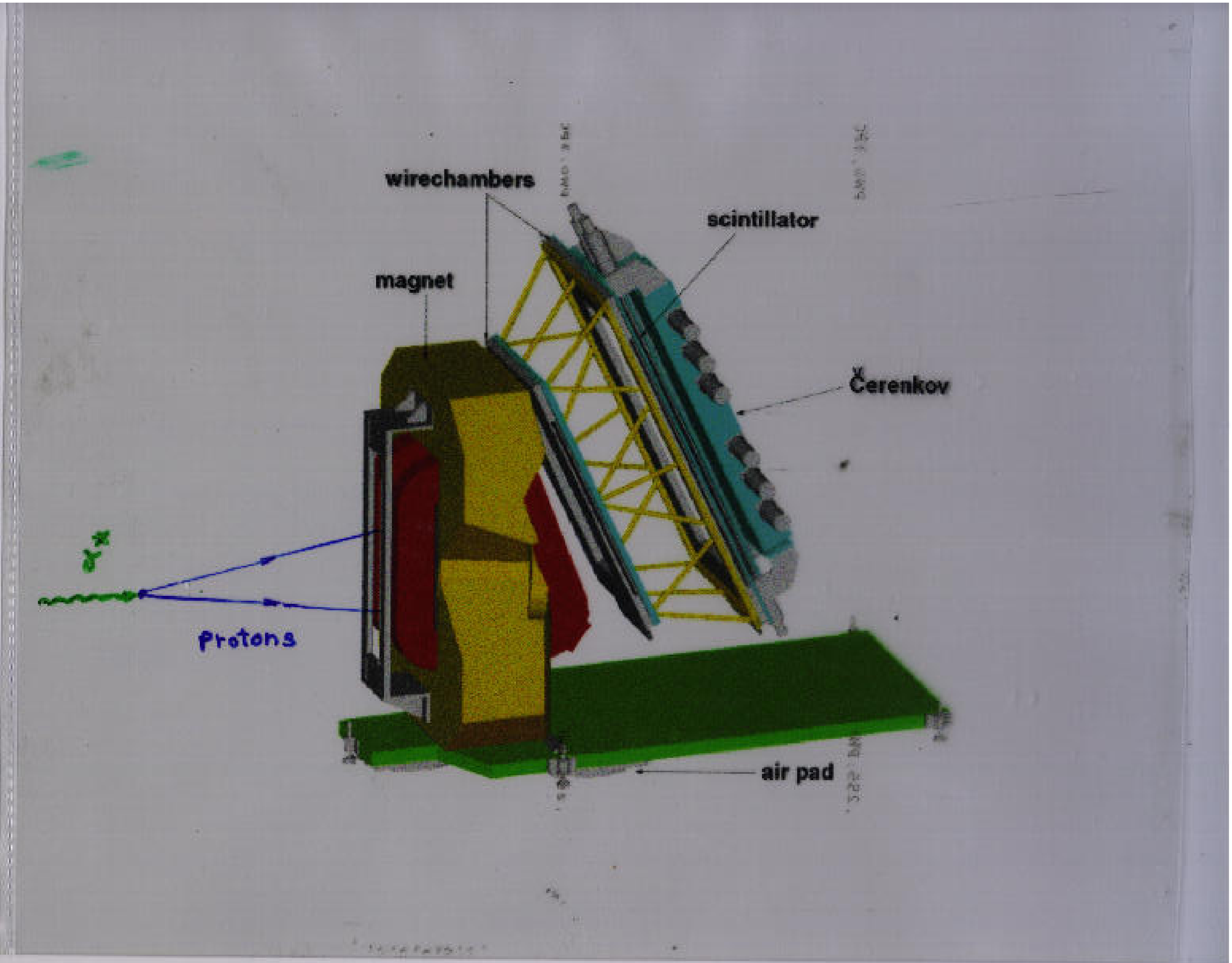
Calorimeter
- BigBite Calibration

BigBite (protons)
- Large Acceptance
- Medium Resolution

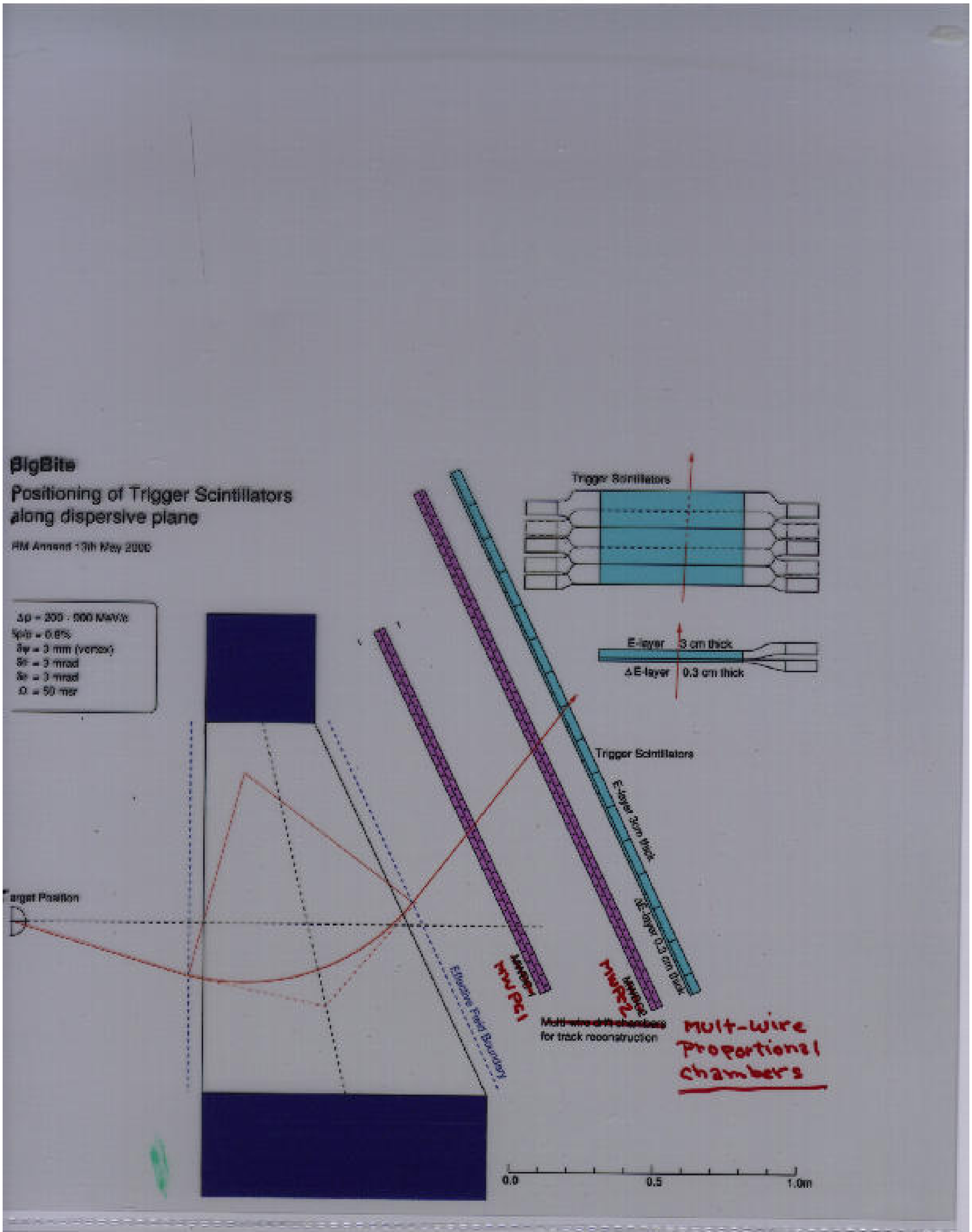
$\Delta\Omega \sim 90$ msr
$P \sim 0.2 - 1$ GeV/c
$\Delta P/P \sim 1\%$

	HRS	BigBite
p-range (MeV/c)	300-4000	200-900
acceptance_H (mr)	±20	±80
acceptance_V (mr)	±60	±300
solid angle (msr)	4.8	96
Δ p/p	10^{-4}	5×10^{-3}
$\Delta\theta_H$ (mr)	0.6	3.2
$\Delta\theta_V$ (mr)	2.0	3.2
measure	$\vec{\ }_e$, vertex	$\vec{p}_p$,vertex
σ_{vertex} (cm)	0.1 (y)	0.32
focusing	$< x\|\theta >\doteq 0$ $< y\|y >= 0$	none

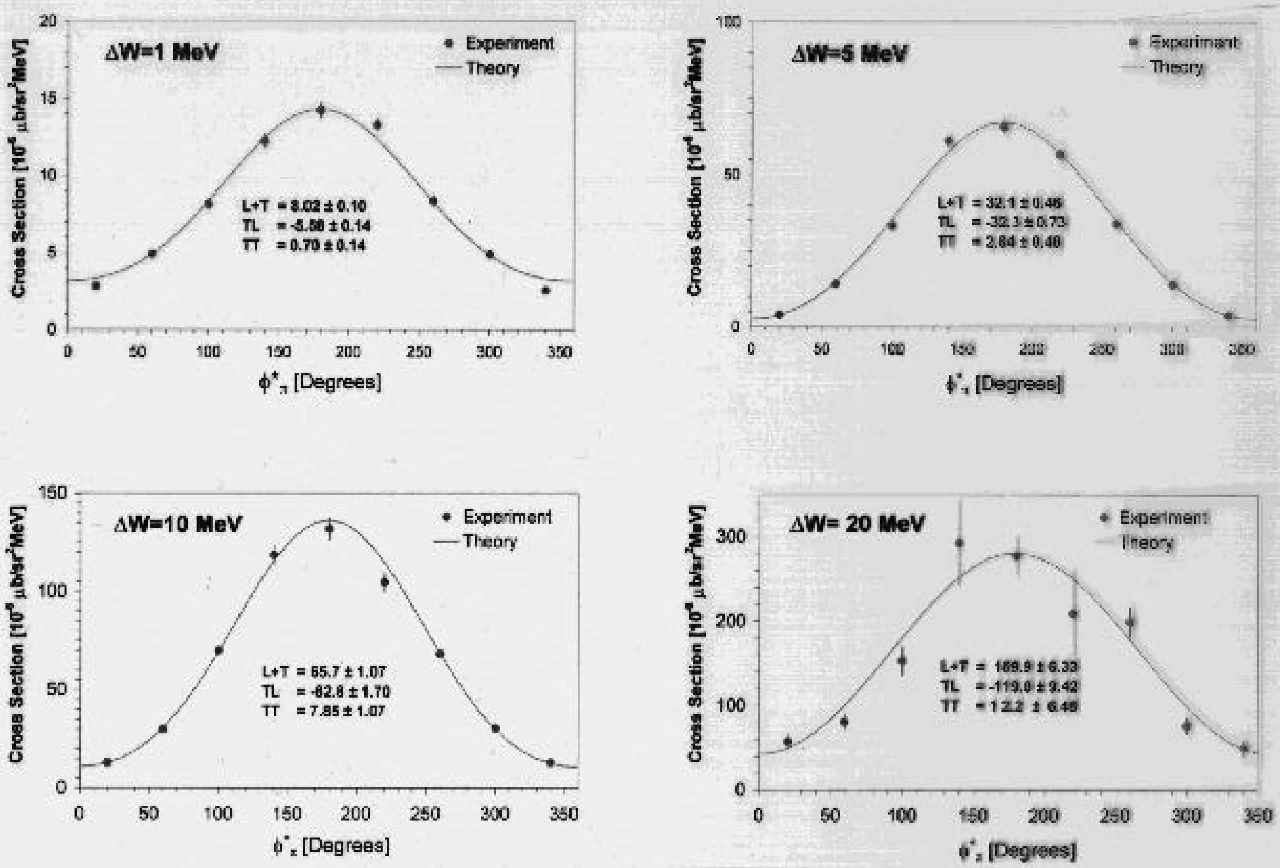
Hydrogen Density	0.07 gm/cm^3
Cell Length	10.0 cm
Cell Diameter	1.0 cm
Cell Material	Al
Entrance window	0.0015 cm
Exit window	0.0015 cm
Side wall	0.0025 cm



wirechambers
scintillator
magnet
Čerenkov
Protons
air pad


BigBite
Positioning of Trigger Scintillators
along dispersive plane
RM Annand 13th May 2000
Trigger Scintillators
E-layer 3 cm thick
ΔE-layer 0.3 cm thick
Trigger Scintillators
Target Position
Effective Field Boundary
MWPC1
MWPC2
Multi-wire drift chambers
for track reconstruction
Mult-wire
Proportional
Chambers
0.0
0.5
1.0m

$E=2400$ MeV, $Q^2=0.04 - 0.05$ [GeV/c]^2, $\theta^*_\pi = 90^\circ$, $\theta_e = 6^\circ$



Expected Results

100 Hrs per Kinematic Setting

18 Bins	Φ_{CM}	20° per Bin
10 Bins	Θ_{CM}	18° " "
20 Bins	W	1 MeV " "
3 Bins	Q^2	0.01 " "

Approximately 5 - 7 % Statistical Accuracy per Point

L+T	$\simeq$	2%	Statistical
TL	$\simeq$	4%	Statistical
TT	$\simeq$	30%	Statistical

Using the SAID partial wave analysis code, this data would provide the following accuracy for the $Q^2 = 0.06[GeV/c]^2$ point.

Wave	—Amplitude—	Error
S31 pE	22.2	1.0
S31 pS	15.4	1.0
P31 pS	2.8	0.9
P33 pM	4.3	0.2