

π^+ Photoproduction
from FROST
Analysis Update

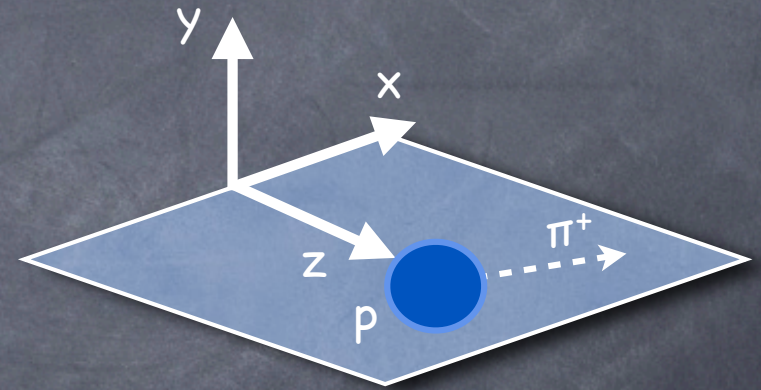
Steffen Strauch
University of South Carolina

CLAS Hadron Spectroscopy Group Meeting, JLab, September 26, 2009

Single- and Double Polarization Observables

- Polarized cross section (beam/target polarization)
g9 Experiment

$$\begin{aligned} \left(\frac{d\sigma}{d\Omega} \right) / \left(\frac{d\sigma}{d\Omega} \right)_{\text{unpol}} &= 1 - P_T \Sigma \cos(2\phi) \\ &+ P_X [-P_T H \sin(2\phi) + P \cdot F] \\ &- P_Y [-T + P_T P \cos(2\phi)] \\ &- P_Z [-P_T G \sin(2\phi) + P \cdot E] \end{aligned}$$



- P_T : transverse beam polarization
- P_{\odot} : degree of circular beam polarization
- P_X, P_Y : transverse target polarization
- P_Z : longitudinal target polarization

I.S. Barker, A. Donnachie, and J.K. Storrow, Nucl. Phys. **B75**, 347 (1975)

Polarization Observable E

- Circularly polarized beam / longitudinally polarized target

$$\left(\frac{d\sigma}{d\Omega} \right) = \left(\frac{d\sigma}{d\Omega} \right)_{\text{unpol}} (1 - P_Z P_\circ E)$$

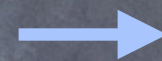
- Estimator

$$\hat{E} = - \frac{\sum x_i}{h P_Z P_\circ \sum x_i^2}$$

$$\sigma^2(E) \geq \frac{1 - h^2 P_Z^2 P_\circ^2 E^2}{h^2 P_Z^2 P_\circ^2 N}$$

$$x_i = +1$$

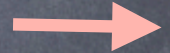
beam
spin



target
spin



$$x_i = -1$$



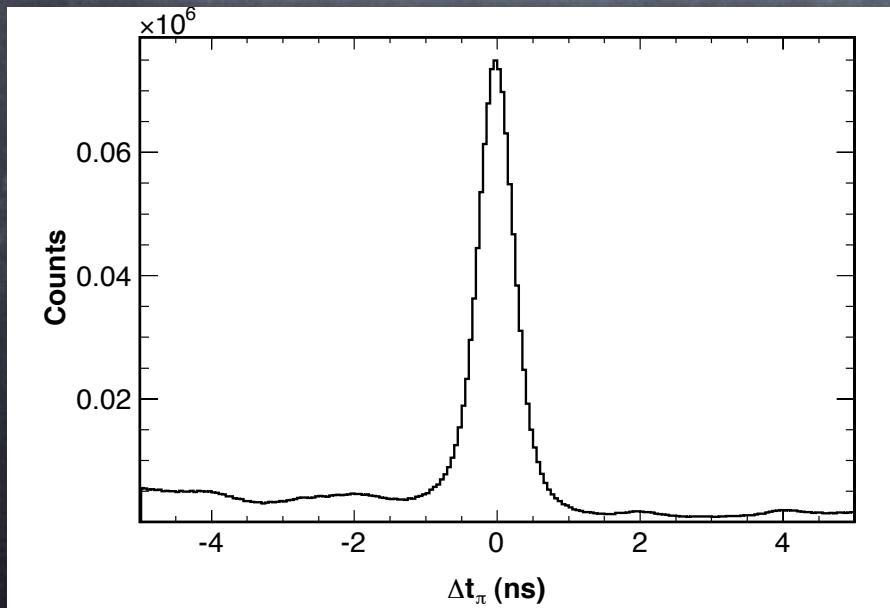
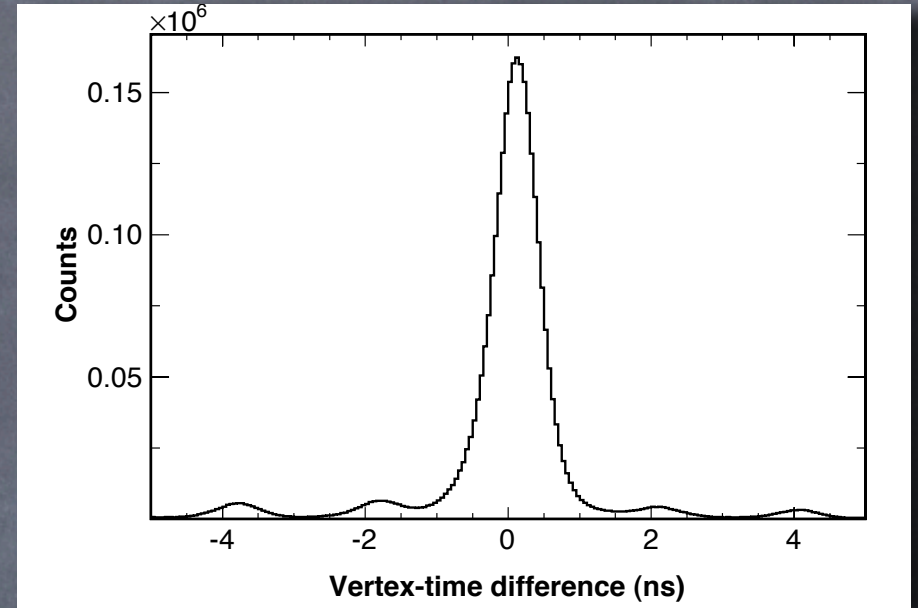
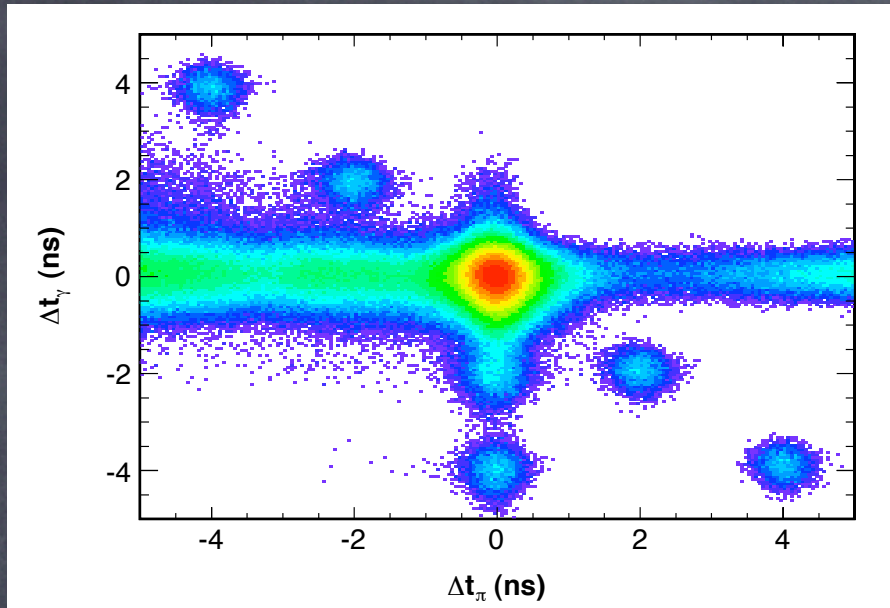
- The sum is running over all events from the butanol target
- Bound-nucleon background is accounted for by the dilution factor h.

π^+ Photoproduction - Event Selection

- One and only one positively charged particle detected with:
 - > hit in ST, SC, and DC
 - > $\beta > 0$, $p > 0$, and $l > 0$
 - > crude pion ID
- No negatively charged particles detected
- Photon with good tagger status, and vertex time closest to that of the pion
- No energy-loss correction, yet



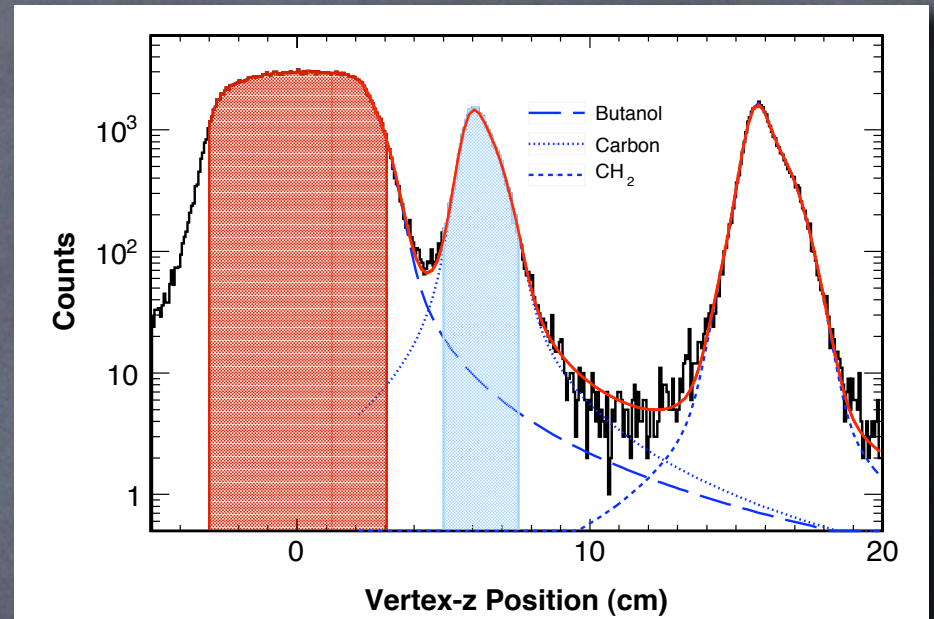
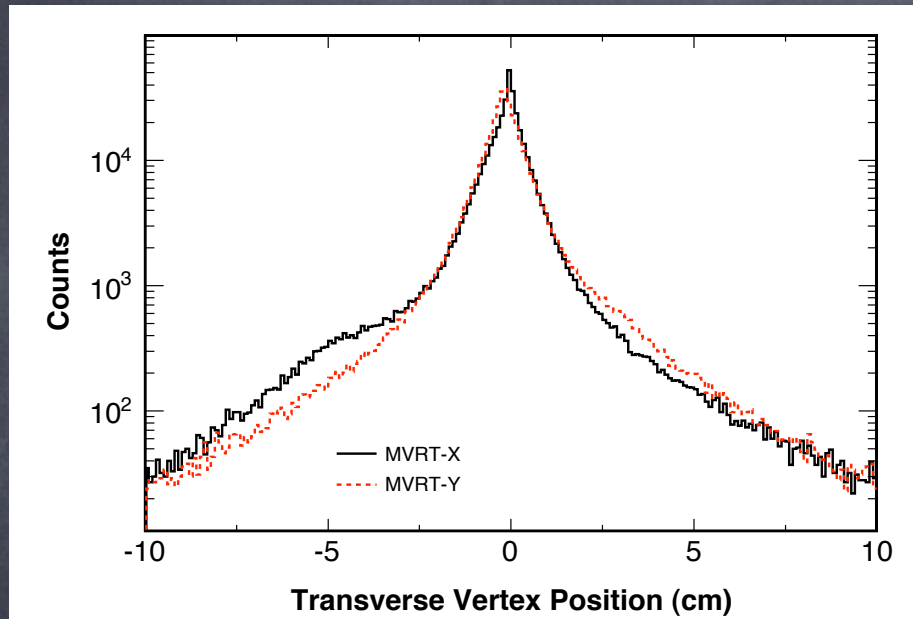
Particle Identification and Photon Selection



- Vertex-time difference: $|\Delta t_\gamma| < 1$ ns
- Particle ID: $|\Delta t_\pi| < 1$ ns

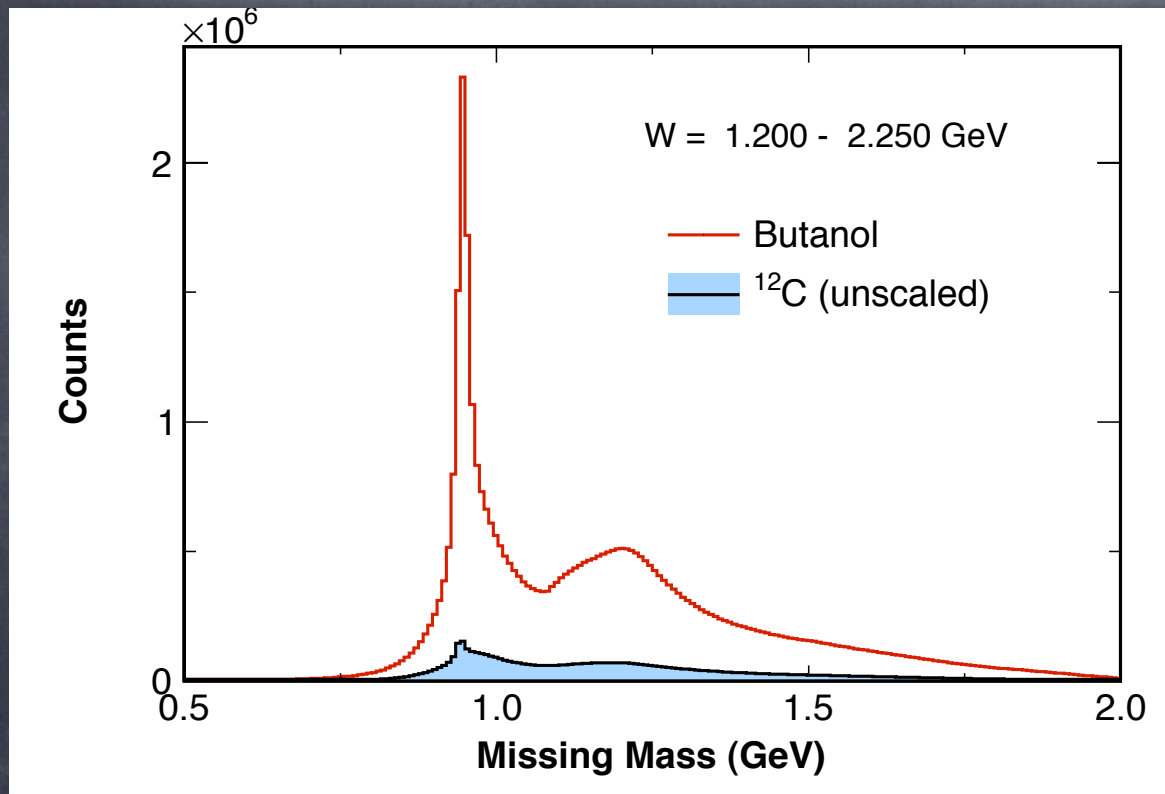
$$\Delta t_\pi = \frac{l}{c} \left(\frac{1}{\beta} - \sqrt{\frac{m_\pi^2}{p^2} + 1} \right)$$

Reaction Vertex



- Butanol events from $Z \in [-3, 3]$ cm, $r < 2$ cm
- Carbon events from $Z \in [5, 7.5]$ cm, $r < 2$ cm
- Butanol background under carbon $\approx 1.3\%$ of total

$\Upsilon(\rho, \pi^+)X$ - Missing Mass Distribution



π^+ production off free and bound nucleons

- Identification of reaction channel;
 $m_X \approx m_N$
- Background from reactions off bound (unpolarized) nucleons \Rightarrow
quenching of the asymmetry signal

Dilution Factor

- Dilution factor

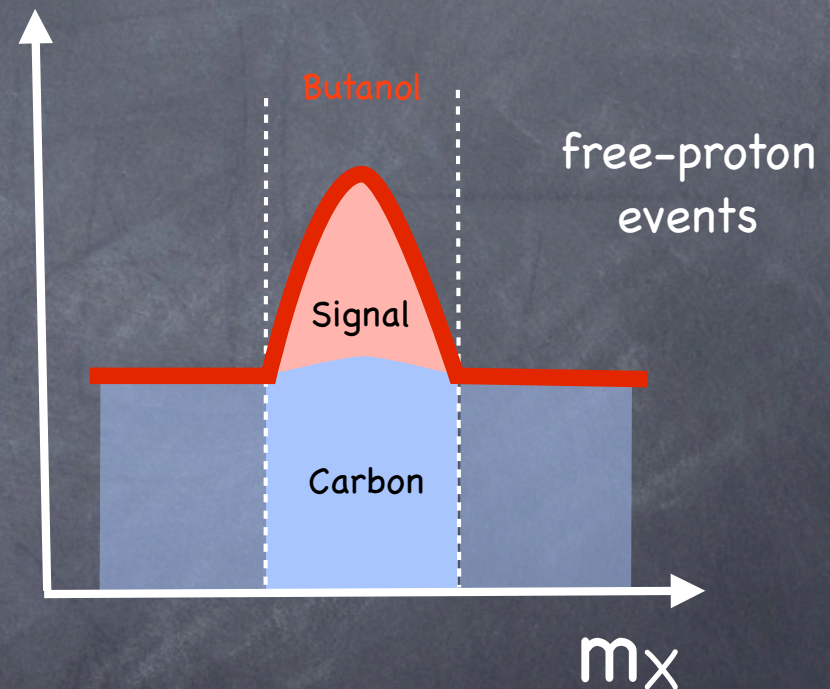
$$h = \frac{S}{B} = 1 - \frac{C}{B}$$

- For the butanol target (C_4H_9OH) the simple estimate is $\approx 10/74 \approx 0.14$
- Statistical uncertainty in E scales as

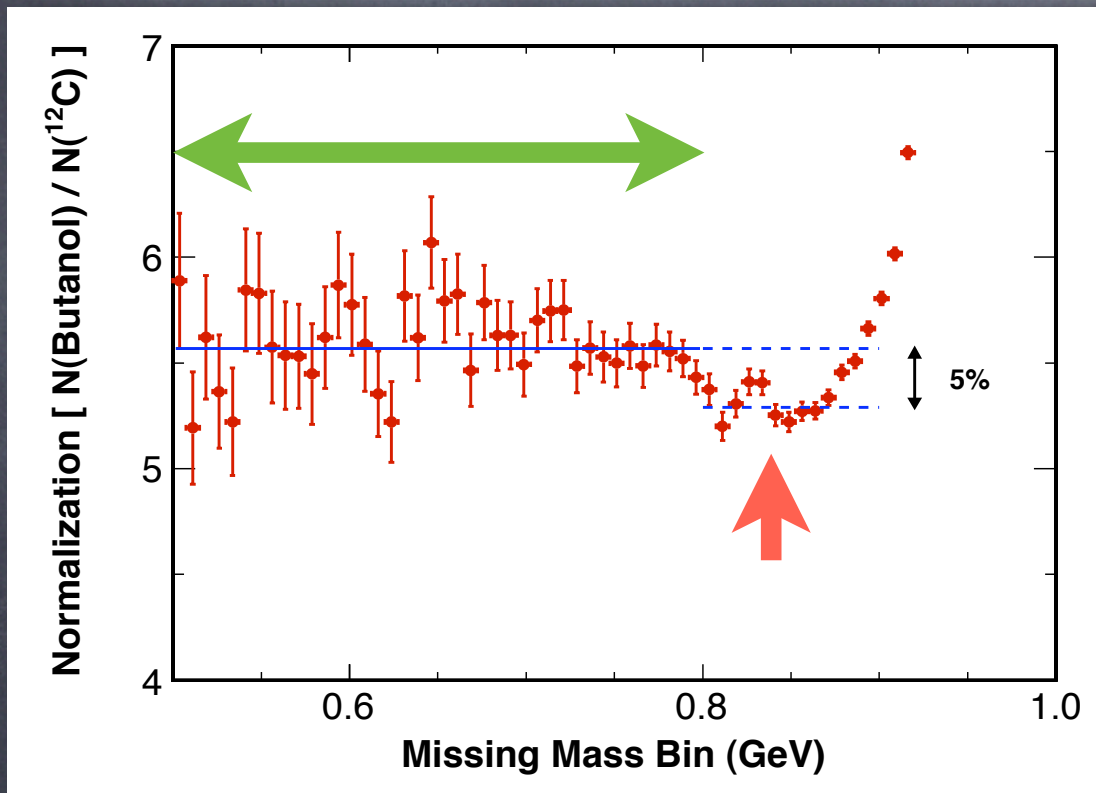
$$\sigma_E \propto \frac{1}{\sqrt{F}}$$

- Figure of merit

$$F = h^2 B$$

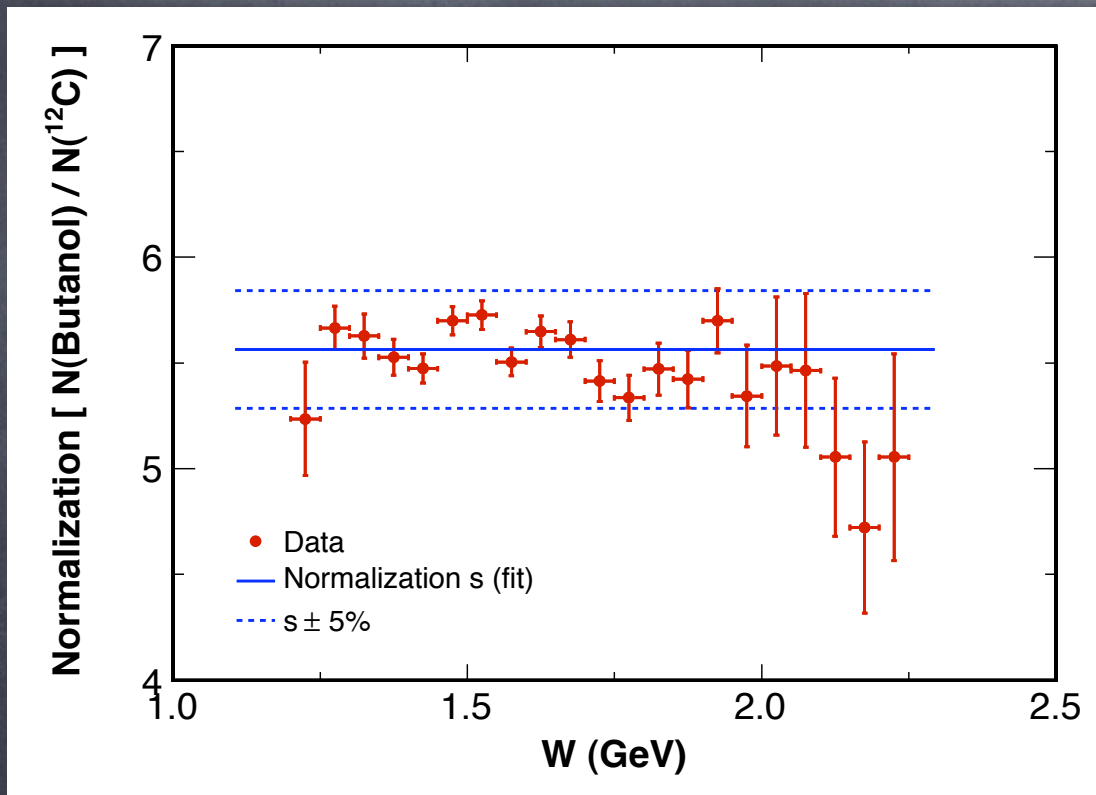


Butanol/Carbon Normalization



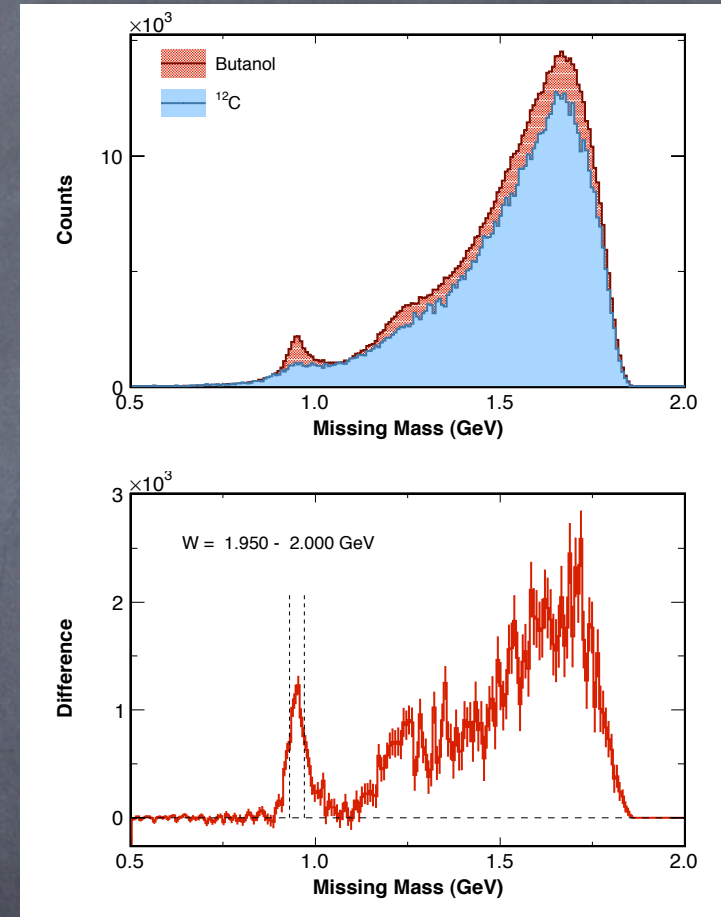
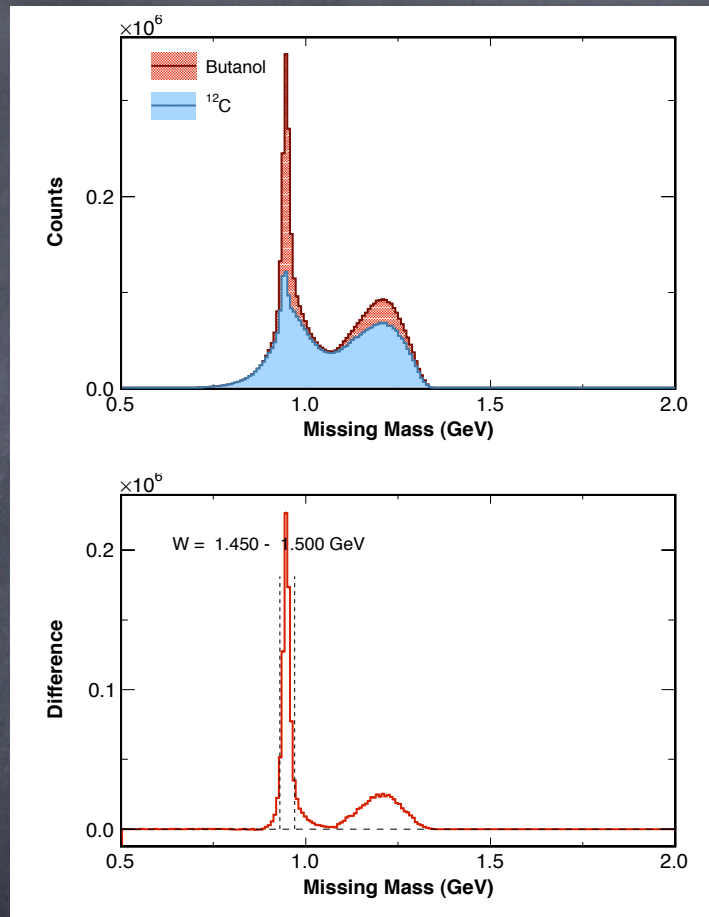
- Missing mass distributions for butanol and carbon data are of the **same shape** up to 0.8 GeV.
- Relatively more butanol events at $\approx m_N$ (expected)
- Depletion** at 0.8 - 0.9 GeV?

Energy Dependence of Normalization



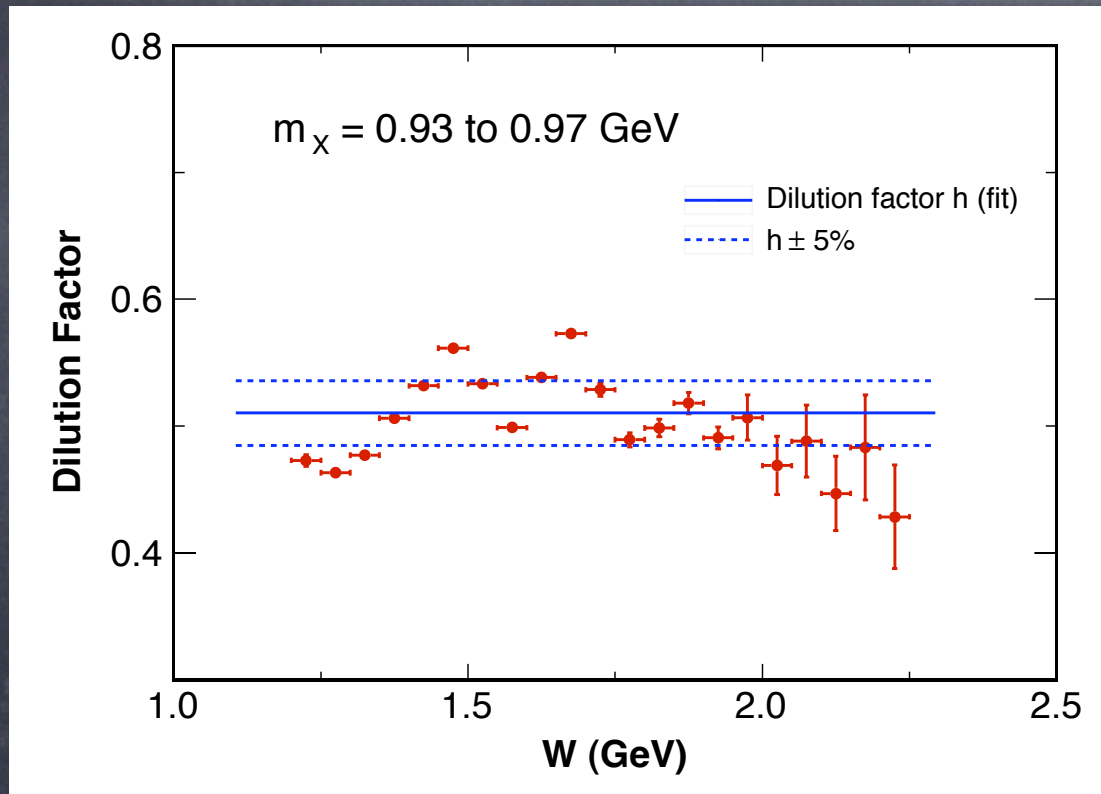
- Normalization factor is **energy independent** within $\pm 5\%$
- Fit $\chi^2/\text{d.o.f} = 35/20$
- Angular dependence not studied, yet

Free-Proton Missing Momentum Distribution



- Carbon data normalized to butanol data for $m_x < 0.8$ GeV
- The difference distribution is for illustration only and not used in the further analysis.

Dilution Factor



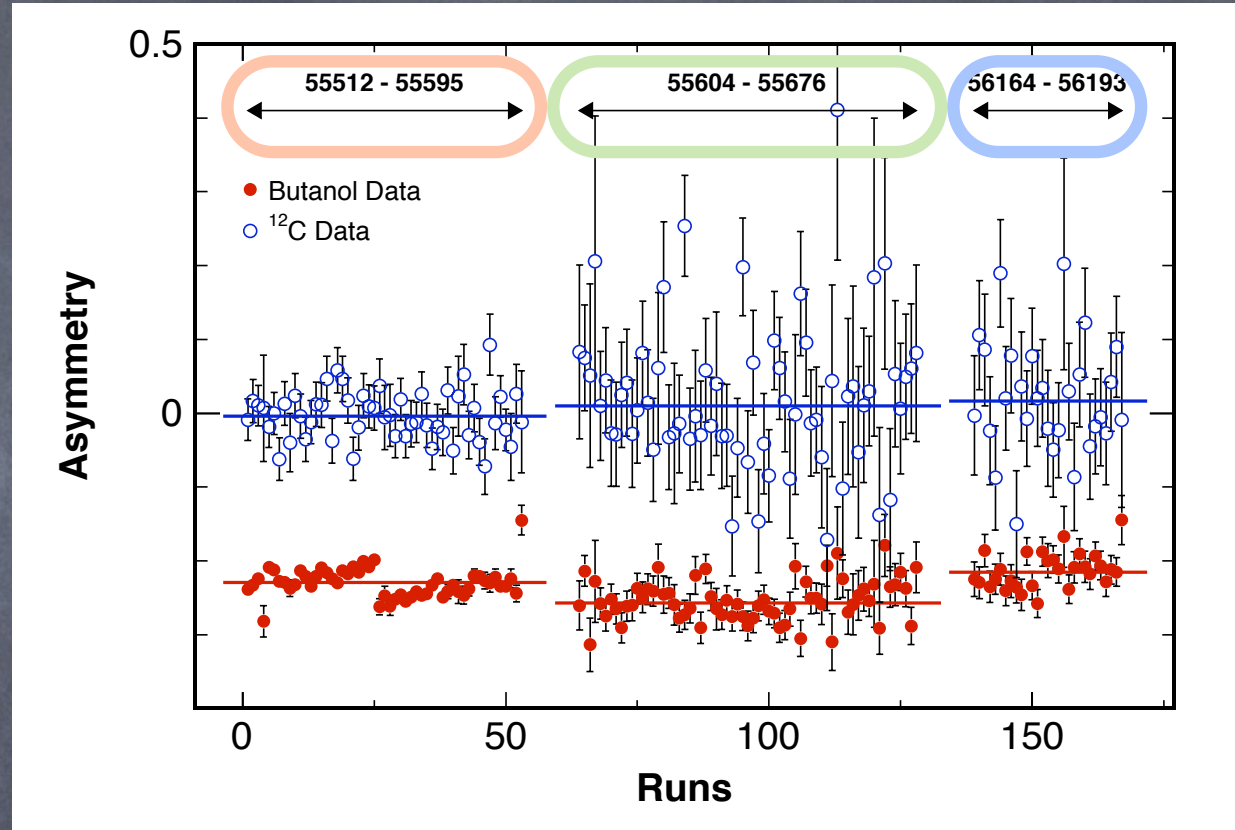
- $h \approx 0.51$; i.e. factor four improvement in this reaction
- Dilution factor decreases for larger W
- Modulation of dilution factor not yet understood
- Angular dependence of the dilution factor to be tested

g9a Runs with Circularly Polarized Beam

#	Run Numbers	E0 (GeV)	Pe (?)	HWP	Holding Field	Target Polarization
1	55521 - 55536	1.645	-	+	+	-
2	55537 - 55555	1.645	-	-	+	-
3	55556 - 55595	1.645	-	+	+	+
4	55604 - 55625	2.478	+	+	-	+
5	55630 - 55678	2.478	+	+	-	-
6	56164 - 56193	2.478	+	+	+	+
7	56196 - 56233	2.478	+	+	+	-

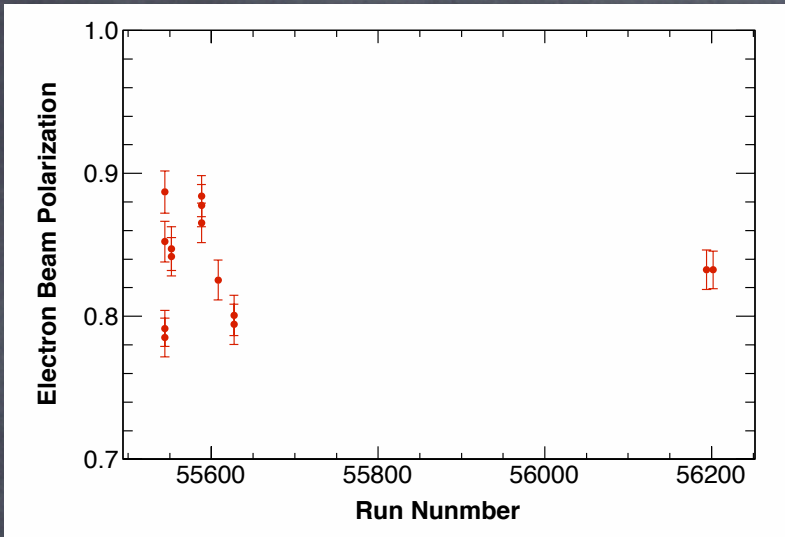
Confirm Polarization Orientations

$$A = \frac{\sum P_i x_i}{\sum P_i^2}$$



- Status of half-wave plate, helicity signal, sign of electron-beam polarization, proton-target spin orientation **understood on a per run base** (up to an even number of sign changes).
- Pion data may help study the time dependence of electron / target polarization

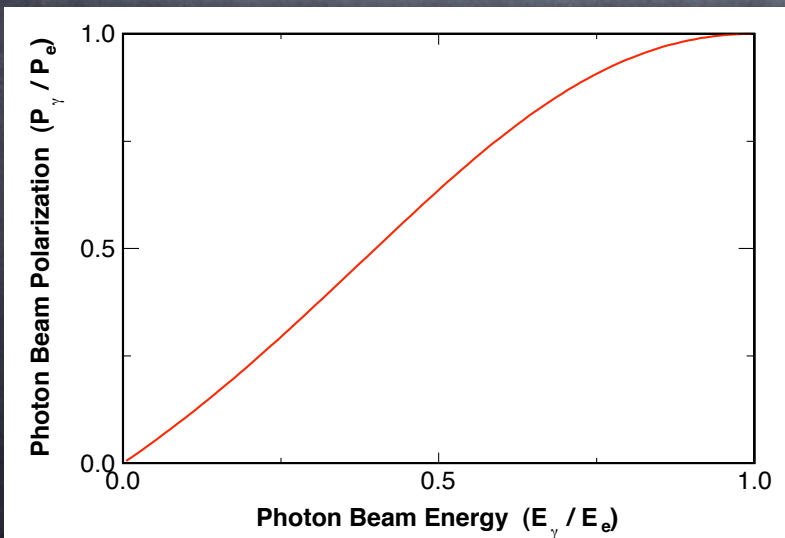
Beam and Target Polarizations



- Photon beam polarization

$$P_e \approx 85\%$$

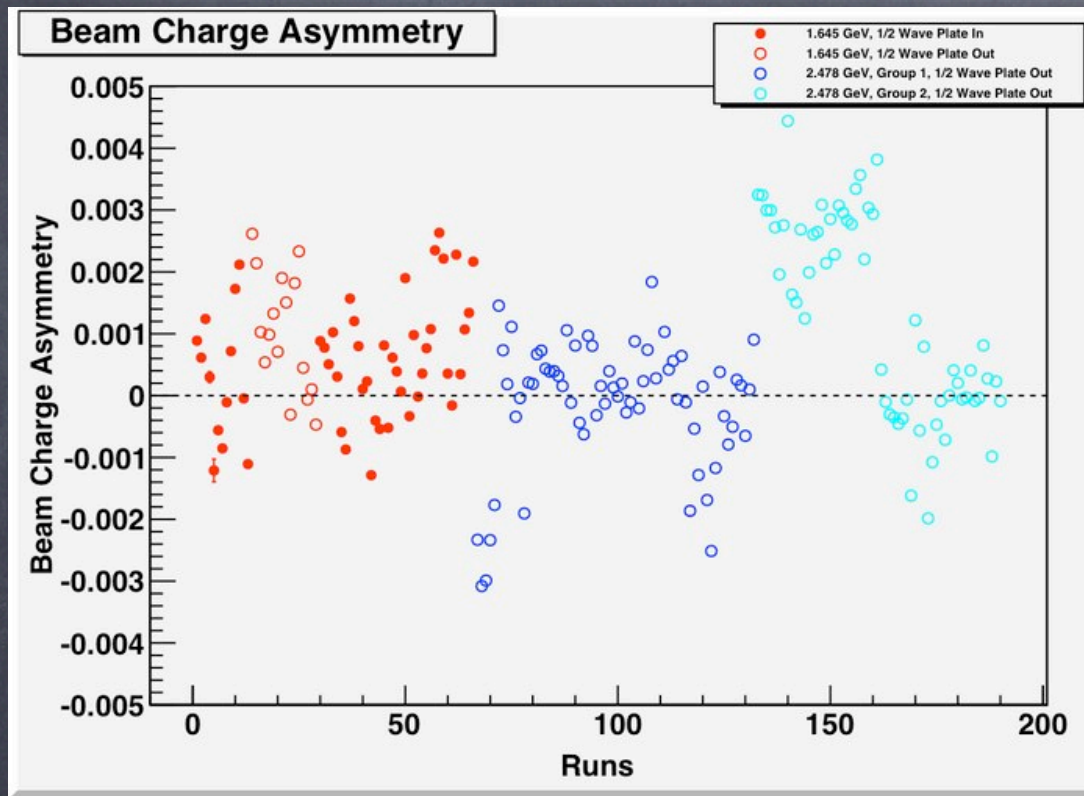
$$P_\gamma = P_e \frac{4x - x^2}{4 - 4x + 3x^2}$$



- Target polarization

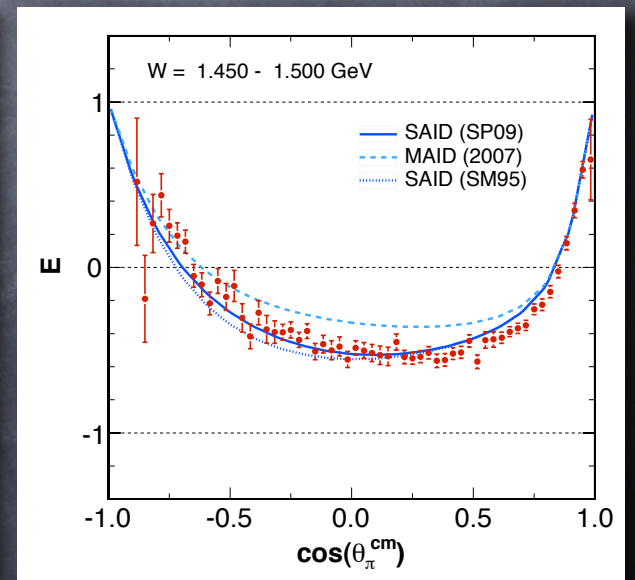
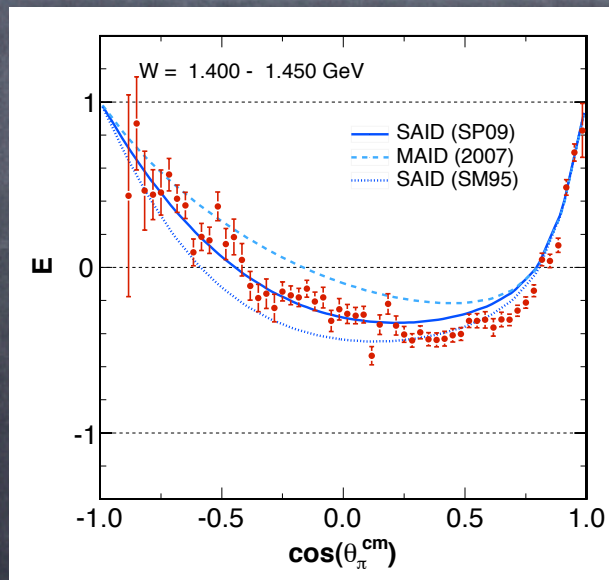
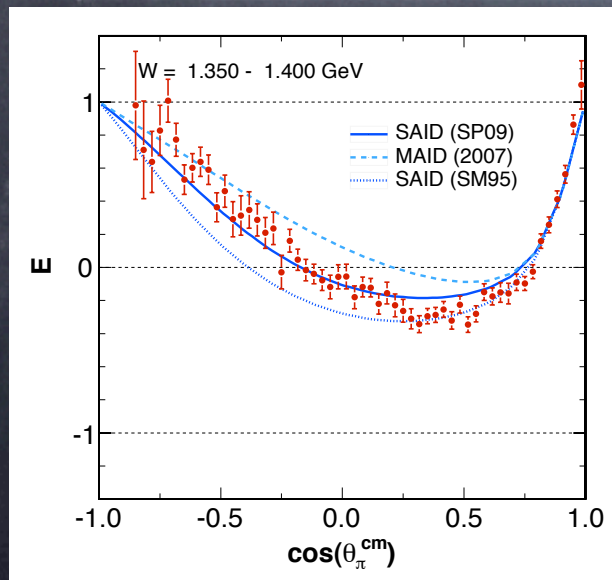
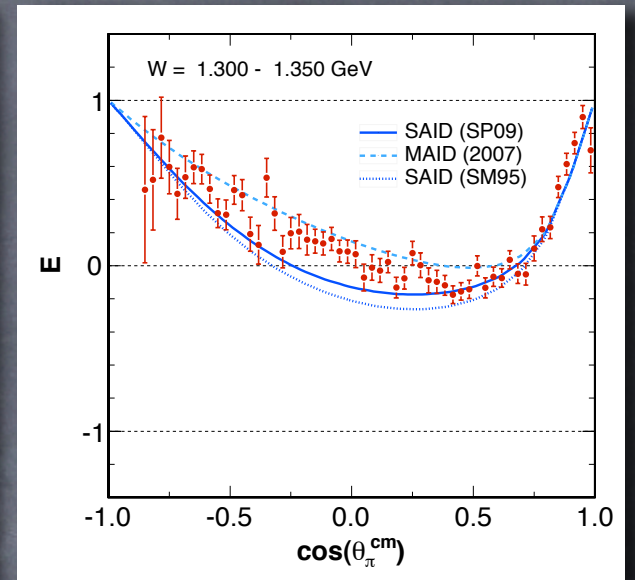
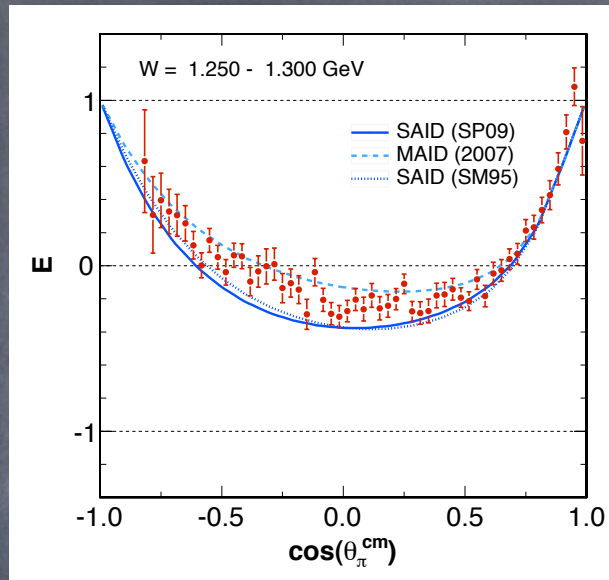
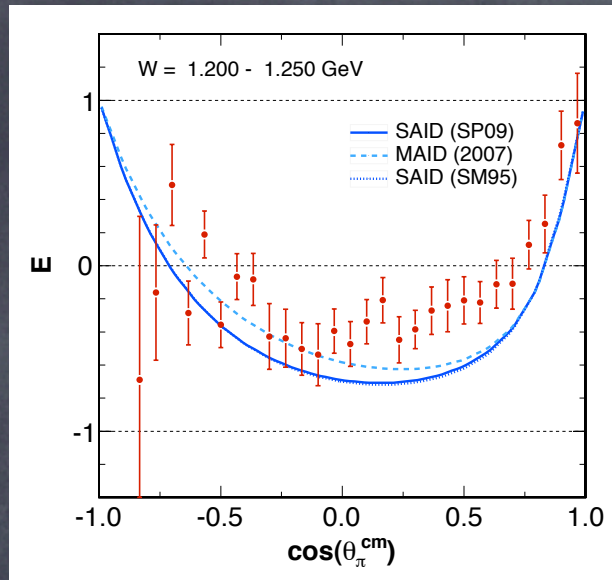
$$P_Z \approx 80\%$$

Beam-Charge Asymmetry

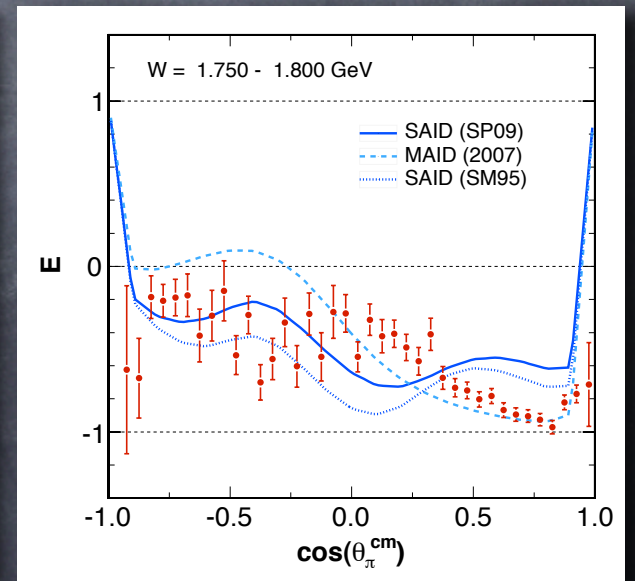
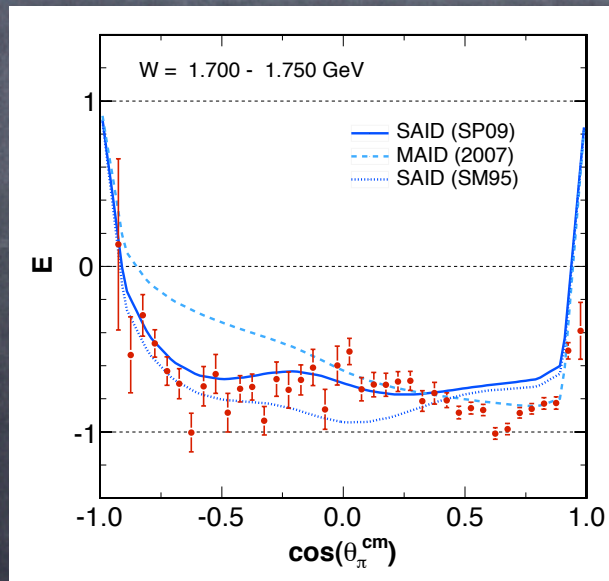
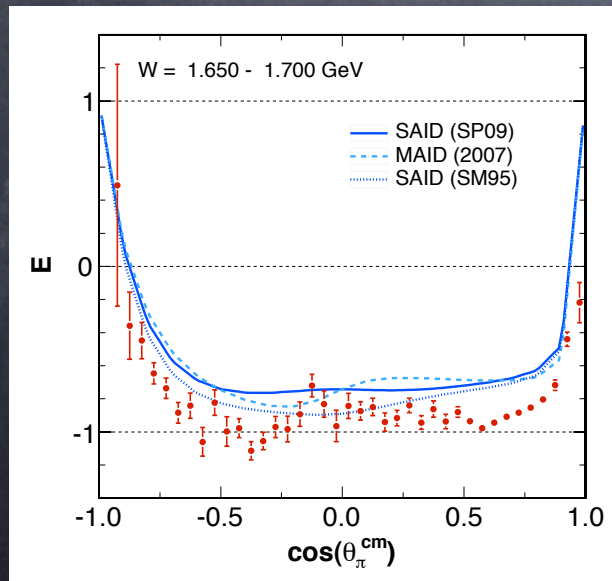
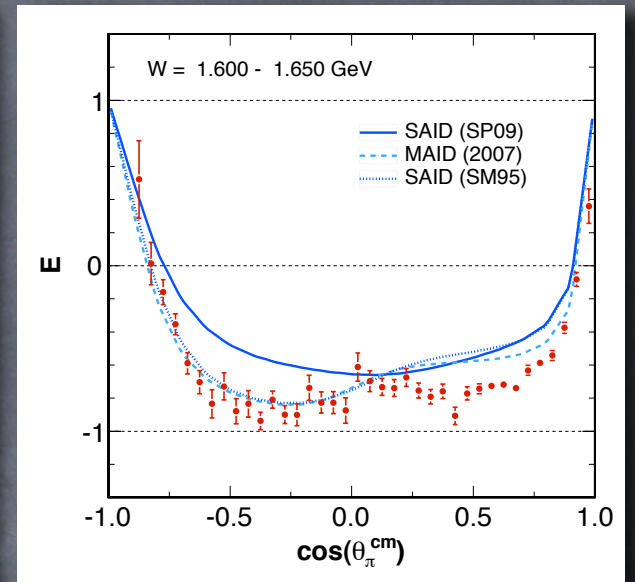
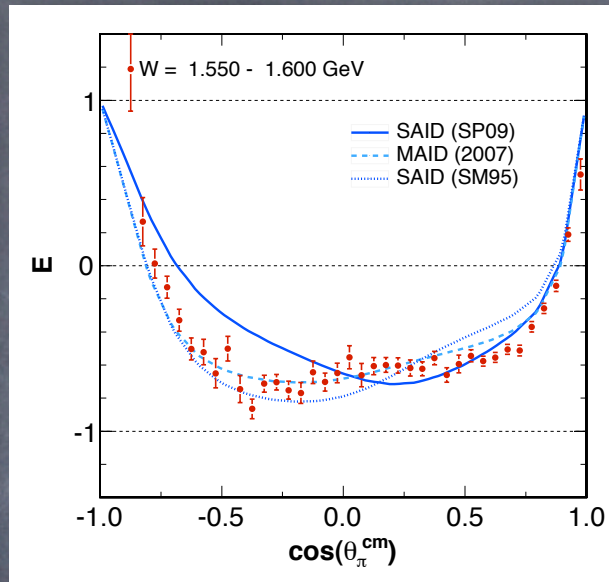
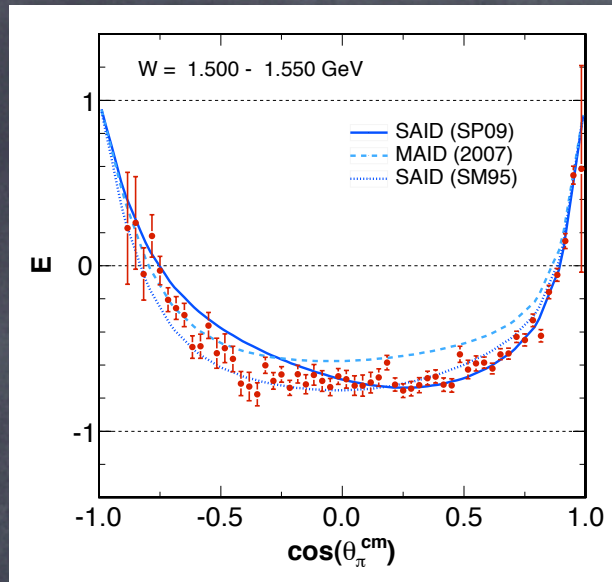


- Helicity-gated beam-charge signals from the synchrotron light monitor in the HLS bank
- All runs have beam-charge asymmetries within $\pm 0.5\%$.

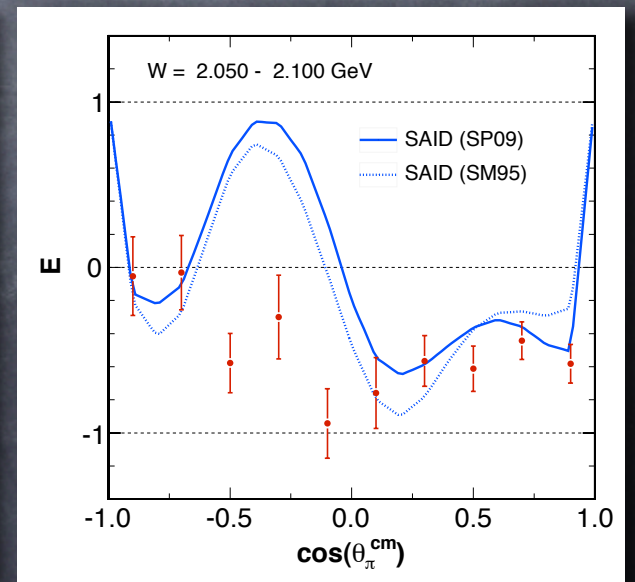
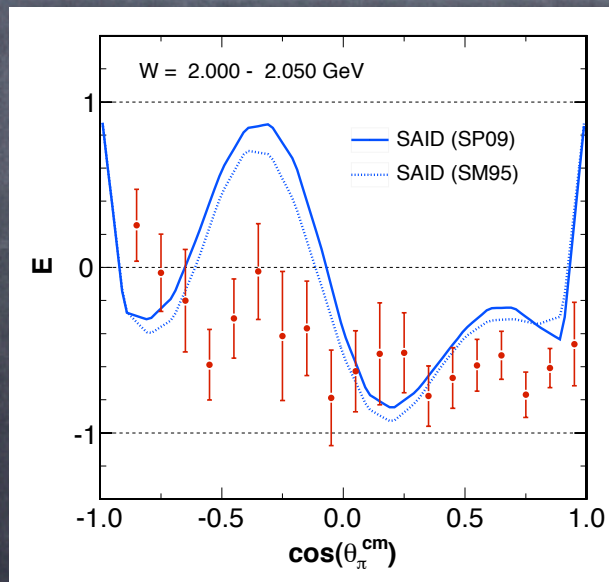
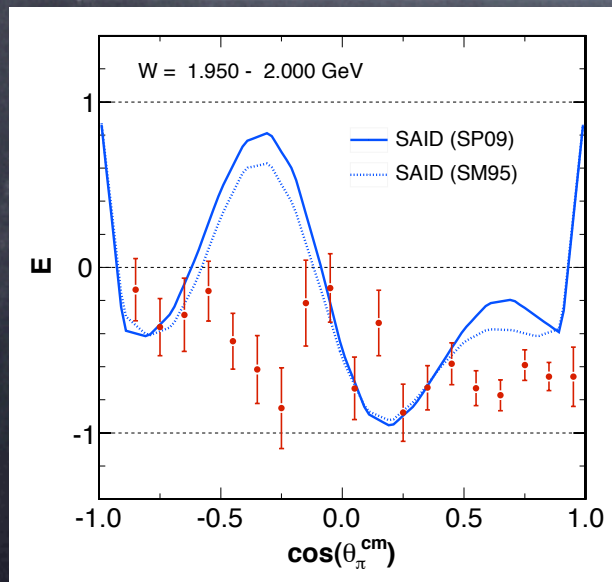
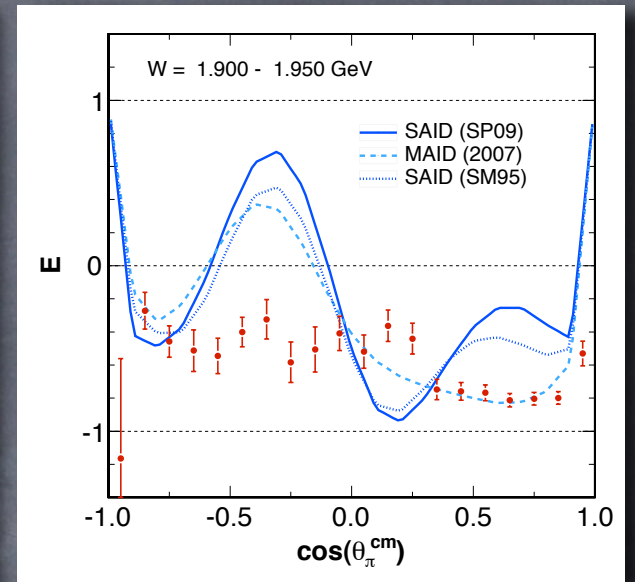
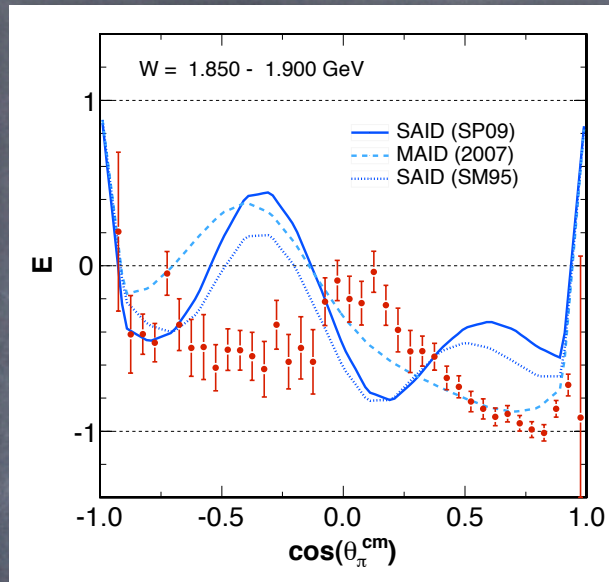
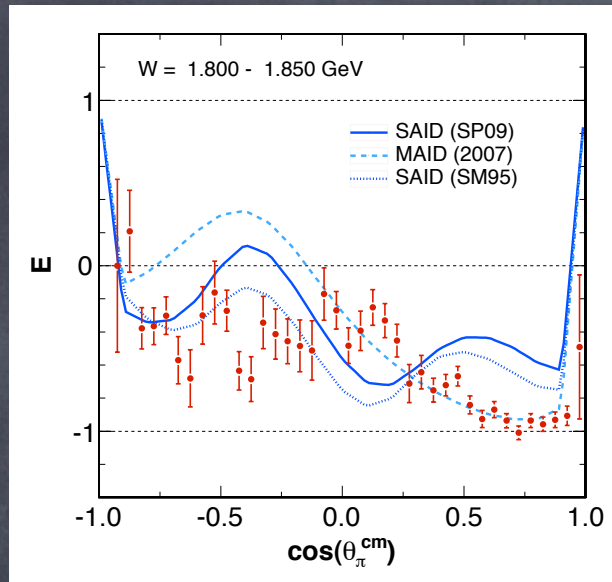
Preliminary Results (I)



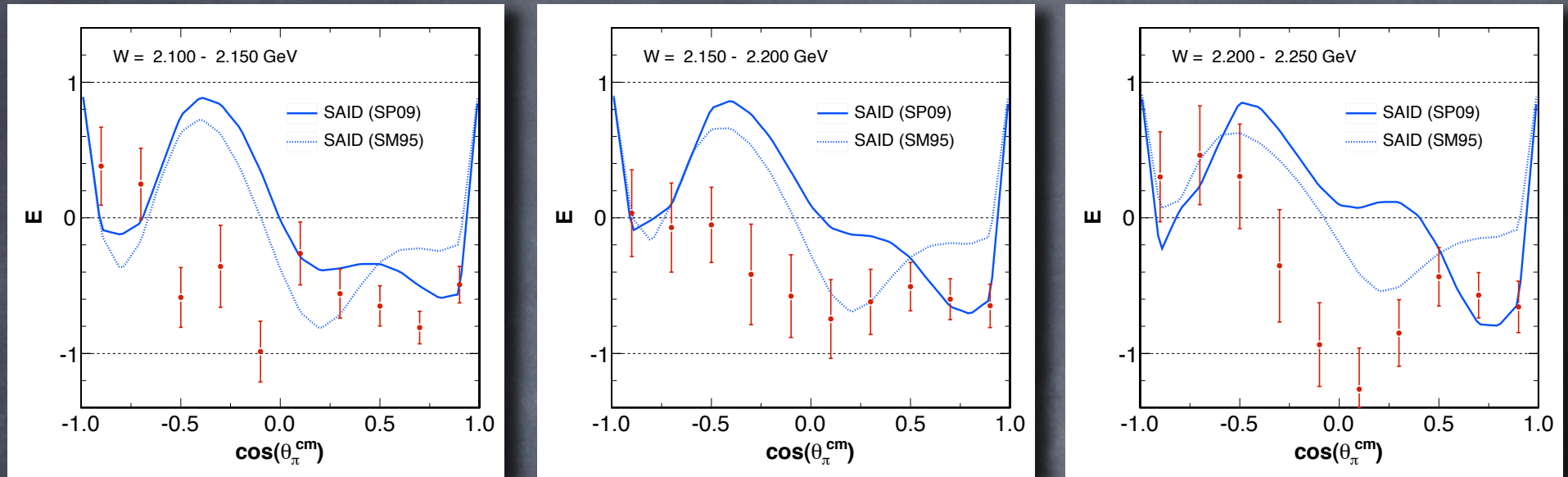
Preliminary Results (II)



Preliminary Results (III)



Preliminary Results (IV)



- Very preliminary results for E in π^+ photoproduction covering a wide energy and angular range.
- $-0.9 < \cos(\theta_{\pi}^{\text{cm}}) < +0.9$
- $1.20 \text{ GeV} < W < 2.25 \text{ GeV}$
- Presently more than 730 data points.

Systematic Uncertainties

present best guesses

Quantity	Uncertainty
Electron-beam polarization	5%
Beam-charge asymmetry	< 0.5%
Photon-beam polarization from P_e	?
Target polarization	?
Dilution factor	5%
Kinematics (W , $\cos(\theta)$)	?
Total	< 10%

Summary

- Very preliminary results for E in π^+ photoproduction
- Issues:
 - > Obtain improved values for electron beam and target polarizations on a per run-period base
 - > Study of systematic effects in dilution factor (carbon/butanol normalization, butanol contamination of carbon data, energy and angular dependence)
 - > Implement energy-loss corrections and study of the reconstruction of event kinematics