

# Update on $\pi^0 \rightarrow e^+e^-e^+e^-$ Fitting

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# Outline

- Physics of the  $\pi^0\gamma\gamma$  Coupling
- Fit Parameters
- Likelihood Function
- Resolution Bias
- MC Studies
- What's Next?

# Physics of the $\pi^0\gamma\gamma$ Coupling

The  $\pi^0\gamma\gamma$  Interaction:

$$\mathcal{L} = -\frac{i}{2M} C_{\mu\nu\rho\sigma} F^{\mu\nu} F^{\rho\sigma} \Phi$$

The Pseudoscalar and Scalar Couplings:

$$C_{\mu\nu\rho\sigma} \sim \frac{f(x_1, x_2; \alpha)}{\sqrt{1 + \kappa^2 + \eta^2}} [\epsilon_{\mu\nu\rho\sigma} + (\kappa + i\eta)(g_{\mu\rho}g_{\nu\sigma} - g_{\mu\sigma}g_{\nu\rho})]$$

The Form Factor: (DIP with  $\beta = -(1 + 2\alpha)$ ,  $\mu = (M_\pi/M_\rho)^2$ )

$$f(x_1, x_2; \alpha) = \frac{1 - \mu(1 + \alpha)(x_1 + x_2)}{(1 - \mu x_1)(1 - \mu x_2)} \sim 1 - \mu\alpha(x_1 + x_2)$$

# The Parameterization

Assuming the  $\pi^0$  is a pure Pseudoscalar:

$\kappa = 0 \quad \eta = 0$ : CP Conserving

$\kappa \neq 0 \quad \eta = 0$ : CP Violating

$\kappa \neq 0 \quad \eta \neq 0$ : CP Violating Plus Phase Difference  
= CPT Violation, New Physics, ...

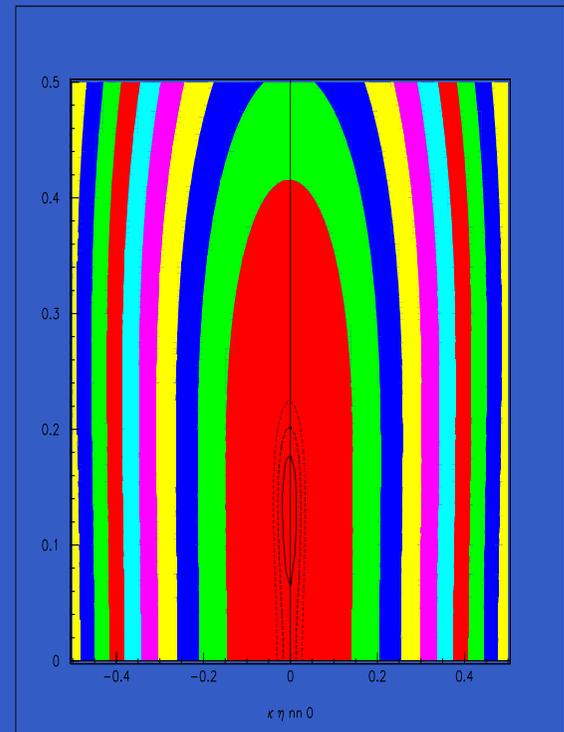
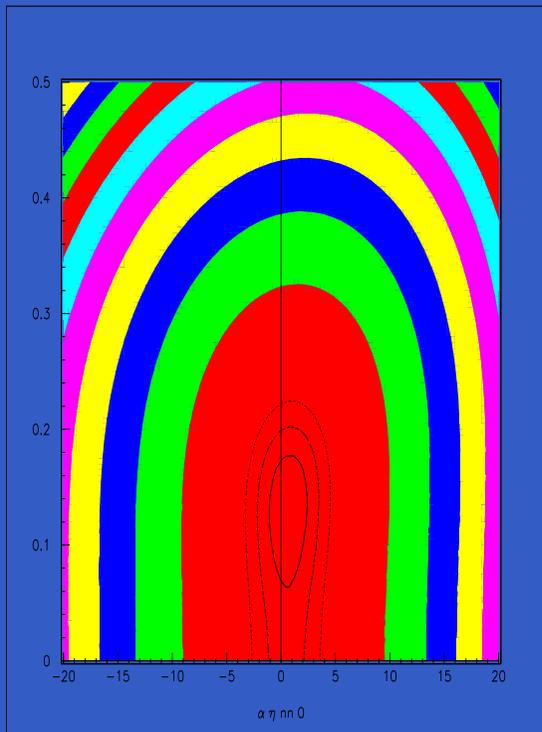
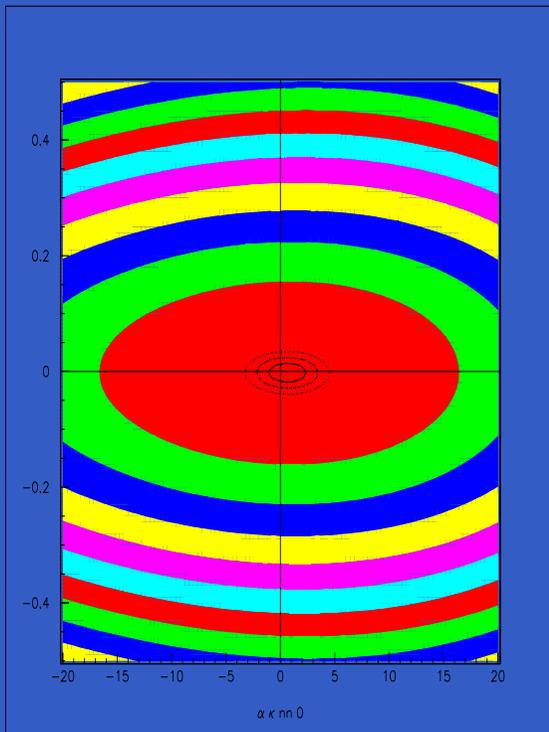
As for the Form Factor:

$\alpha = 0$  : Flat Form Factor

$\alpha = -1$  : Measured in  $\pi^0 \rightarrow ee\gamma$

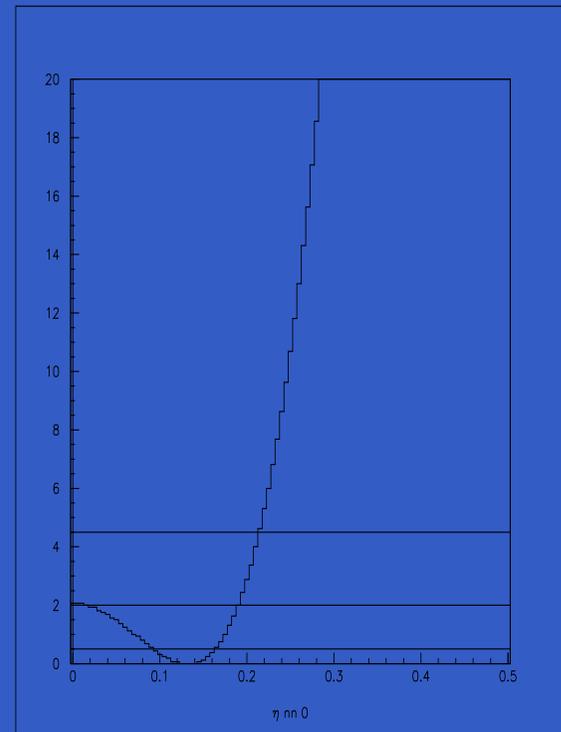
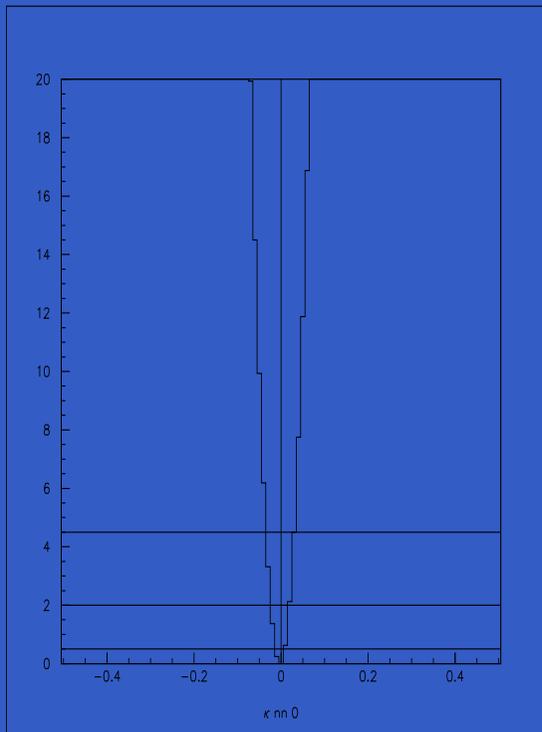
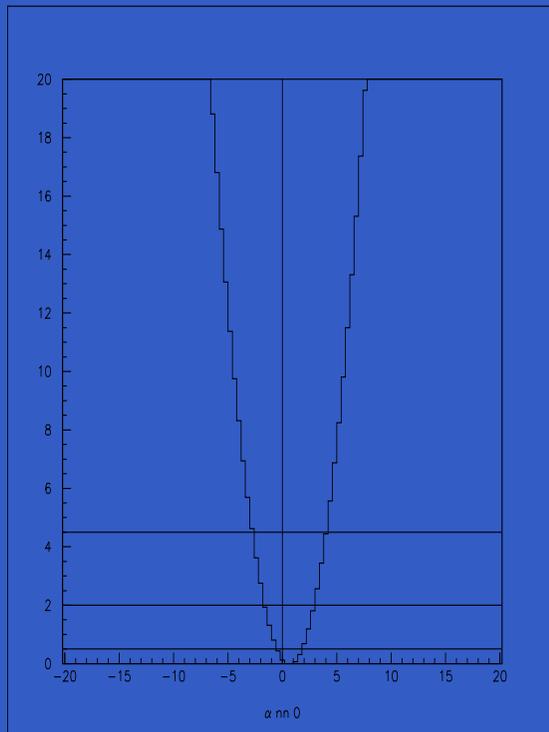
# 3-D Likelihood Fit

The 3 2-D slices taken at the minimum of the third parameter.



# Fit Values

The 3 1-D distributions are fit to second order polynomials with 1,2,and 3  $\sigma$  bands.



# Reminder about Resolution

The shape of the  $\phi$  distribution is given by

$$\frac{d\Gamma}{d\phi} \sim 1 - A \cos 2\phi + B \sin 2\phi$$

where  $A \sim -0.2 \cos 2\phi$  and  $B \sim 0.2 \sin 2\phi \cos \delta$ .

When  $\kappa \sim 0$  and  $\eta \neq 0$ :

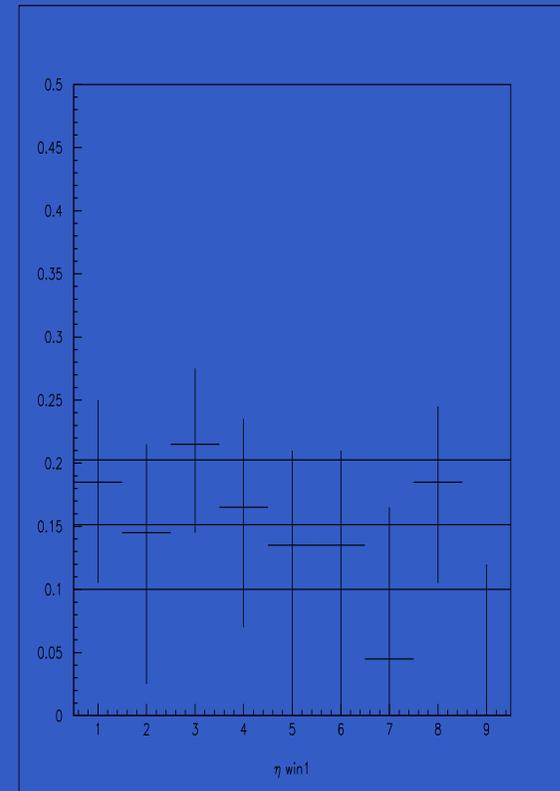
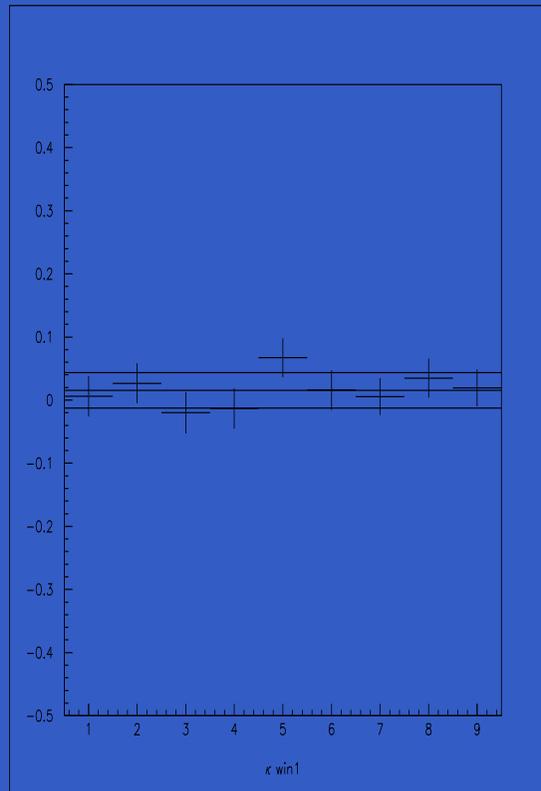
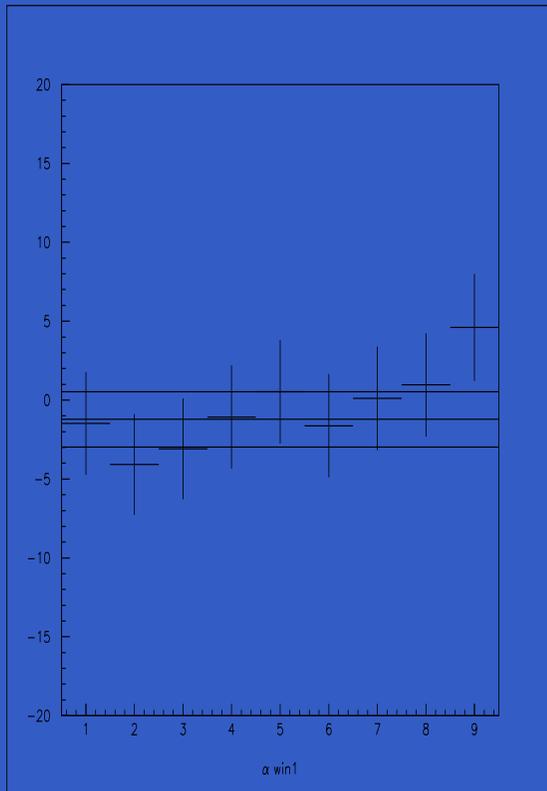
$$A \sim -0.2(1 - 2\eta^2)$$

$$B \sim 0$$

The observed amplitude  $A$  is always smaller than expected due to resolution which in turn pulls  $\eta$  away from zero.

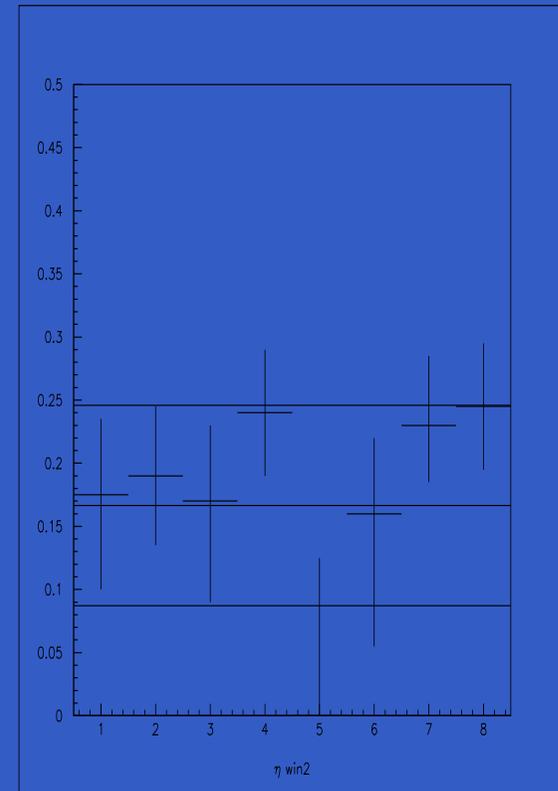
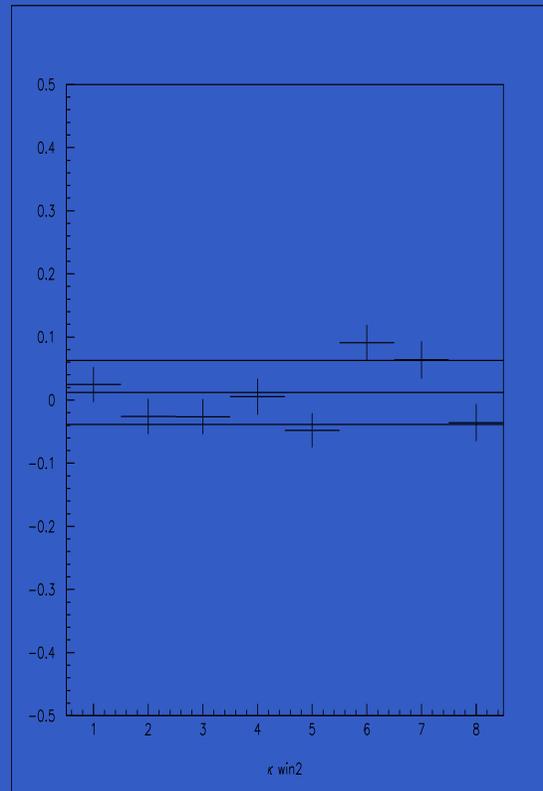
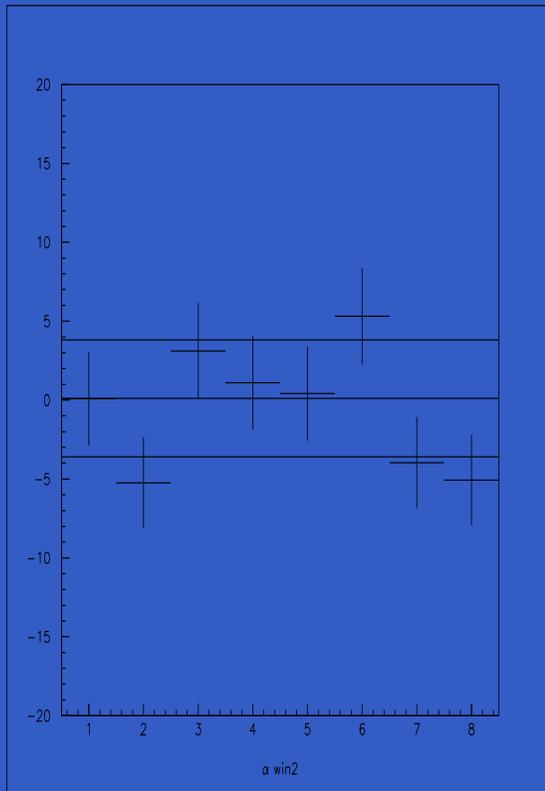
# MC Studies

Fit Results from Win1 MC samples generated with  $\alpha = 0$ ,  $\kappa = 0$ ,  $\eta = 0$ . Last point is DATA.



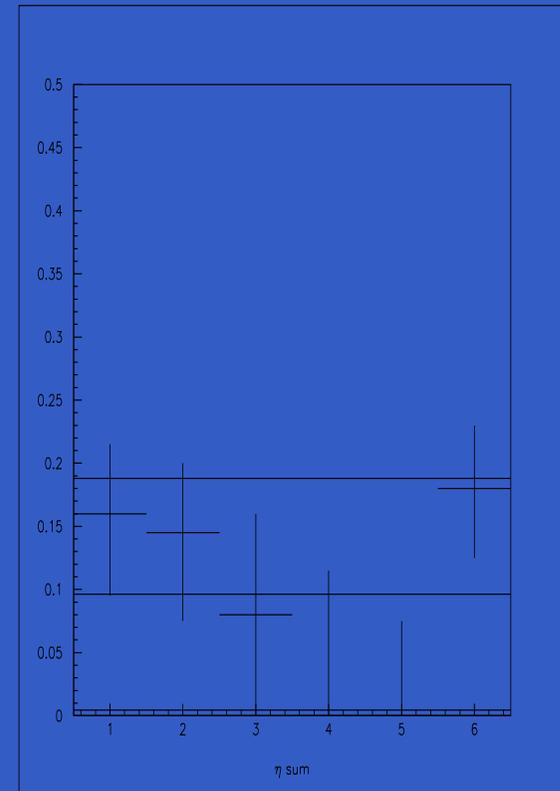
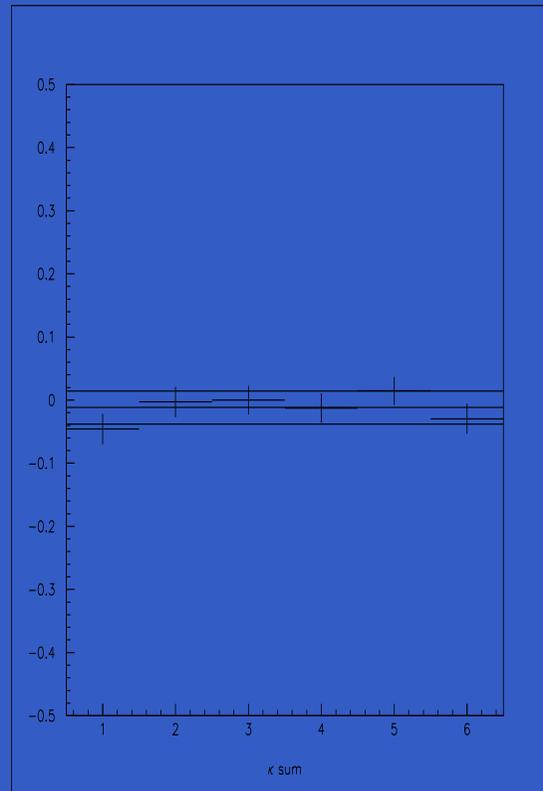
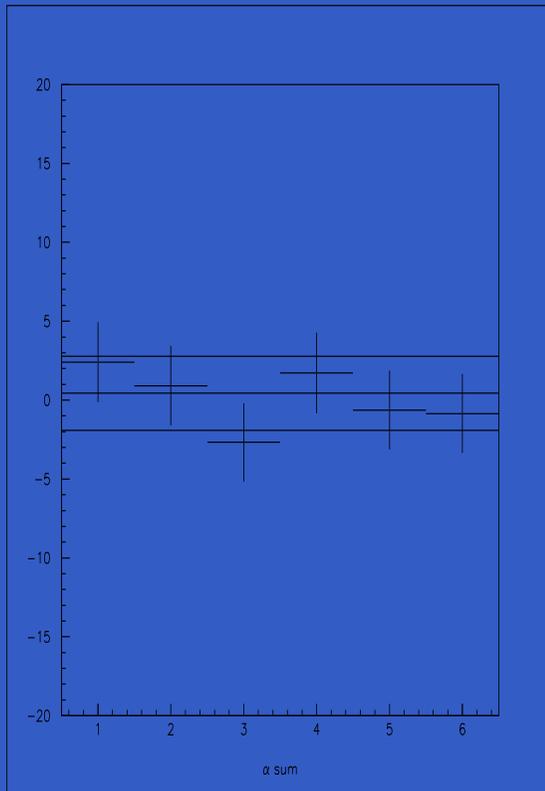
# MC Studies (cont)

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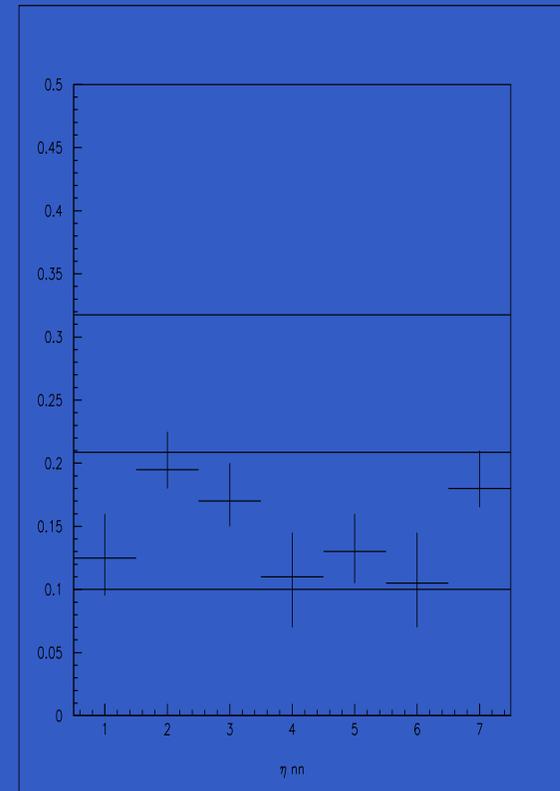
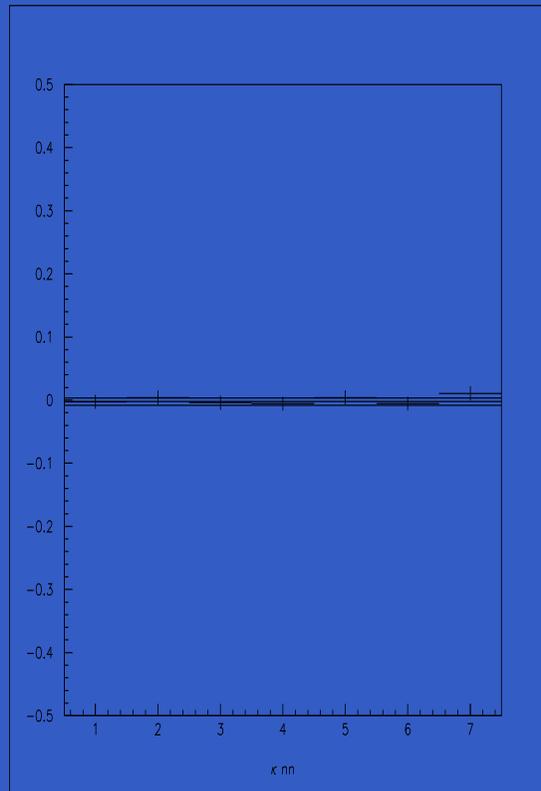
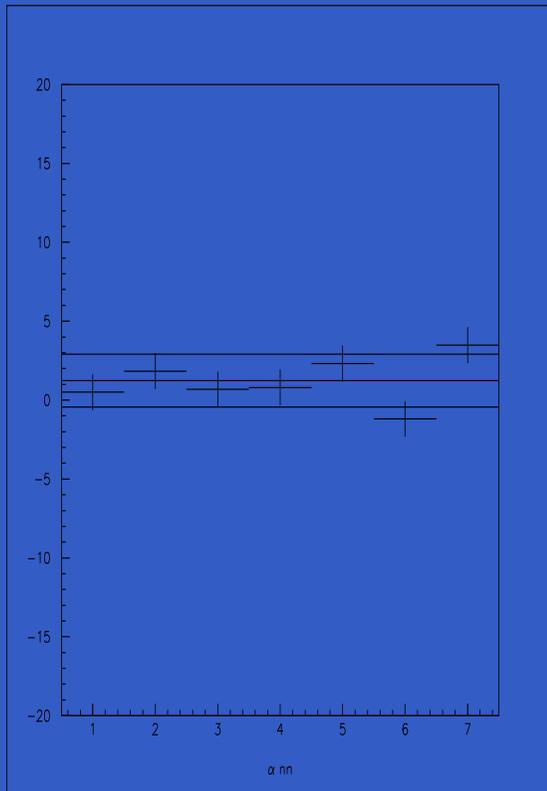
# MC Studies (cont)

Fit Results from Sum MC samples generated with  $\alpha = 0$ ,  $\kappa = 0$ ,  $\eta = 0$ . Last point is DATA.



# MC Studies (cont)

Fit Results from 99 MC samples generated with  $\alpha = 0$ ,  $\kappa = 0$ ,  $\eta = 0$ . Last point is DATA.



# MC Studies Conclusion

- The fit procedure reliably finds the generated values of  $\alpha$  and  $\kappa$  in the MC.
- The errors on  $\alpha$  and  $\kappa$  extracted from the fit agree well with the observed statistical spread.
- The extracted value of  $\eta$  is biased by the resolution on the angle  $\phi$ . I plan on studying the details of the bias and correcting for it in the final result.

# What's Next?

- Systematic Studies:
  - Variation of Cuts
  - DC Resolution and Inefficiencies
  - CsI Resolution
- Increase Normalization Statistics
- Correct Resolution Bias