Background Estimates for the CP Violating Decay

$$\eta \to \pi^0 \pi^0$$

RM: JLab PRIMEX meeting 10/3/08

Study of $\eta \rightarrow \pi^0 \pi^0$ Reaction

- The Origin of CP violation is still a mystery
- CP violation is described in SM by the phase in the Cabibbo-Kobayashi-Maskawa quark mixing matrix. A recent SM calculation predicts BR($\eta \rightarrow \pi^0 \pi^0$)<$3 \times 10^{-17}$
- The $\eta \rightarrow \pi^0 \pi^0$ is one of a few available flavor-conserving reactions listed in PDG to test CP violation. (Maybe the only CP test that can be done at Jlab? RM)
- Current experimental limit in PDG is BR($\eta \rightarrow \pi^0 \pi^0$)<$4.3 \times 10^{-4}$
- Unique test of P and PC symmetries, and search for new physics beyond SM

η Decay Modes

Decay Mode	Branching Ratio	Physics Highlight
All Neutrals	$(71.6 \pm 0.4)\%$	
2γ	$(39.3 \pm 0.3)\%$	SU(3) octet-singlet mixing
$3\pi^0$	$(32.2 \pm 0.3)\%$	χPTh; $m_u - m_d$
$\pi^0\gamma\gamma$	$(3.2 \pm 0.9) \times 10^{-4}$	χPTh, $O(p^6)$
$2\pi^0$	$< 4.3 \times 10^{-4}$	P and CP
$4\pi^0$	$< 6.9 \times 10^{-7}$	P and CP
$\pi^0\pi^0\gamma$	$< 5 \times 10^{-4}$	C (isoscalar)
$\pi^0\pi^0\pi^0\gamma$	$< 4.7 \times 10^{-5}$	C (isovector)
3γ	$< 4.5 \times 10^{-5}$	C (isovector, isoscalar)
4γ	$< 2.8\%$	
$\pi^0\pi^0\gamma\gamma$	$< 3.1 \times 10^{-3}$	χPTh, New Physics
$\nu_e\overline{\nu_e}$	$< 2.8\%$	New Physics, leptoquarks
$\nu_e\bar{\nu}_\mu$	$< 2.8\%$	New Physics, leptoquarks
$\nu_e\nu_e$	$< 2.8\%$	New Physics, leptoquarks
$\gamma\nu\overline{\nu}$	$< 2.8\%$	New Physics, leptoquarks
$\pi^0\nu\overline{\nu}$	$< 2.8\%$	New Physics, leptoquarks

Experimental approaches:

1. Inclusive production in $\gamma p \rightarrow \eta X$ interactions

- Look for 4 gamma events that reconstruct to $\pi^0\pi^0$
- These events should reconstruct to the η
- What are the backgrounds? How do you know you've accounted for all of them

2. Tagged η production in Primakoff production

$$\gamma\gamma \rightarrow \eta \rightarrow \pi^0\pi^0$$

- In addition to above requirements, the events will be elastic, and peaked at very forward angles. Use this constraint to reject backgrounds.

Background in Tagged η Production

The physics background we know very well: $\gamma\gamma \to \pi^0\pi^0$

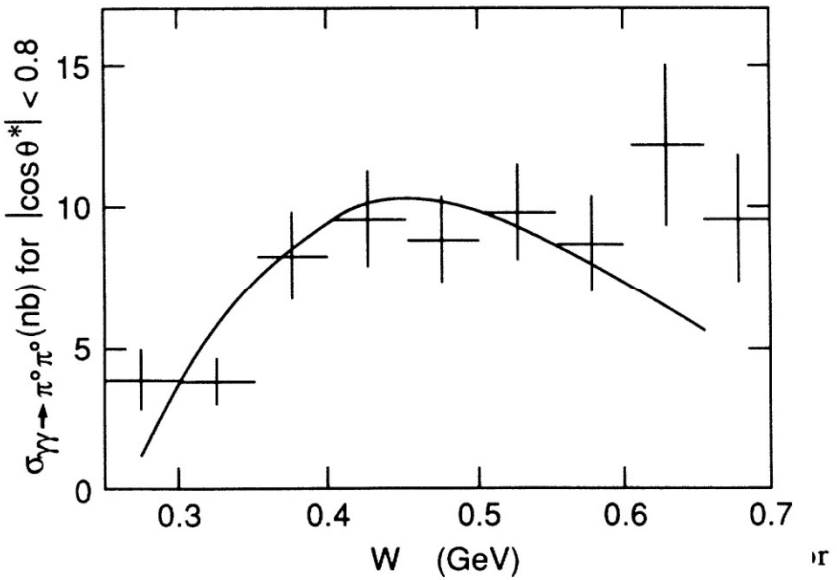


FIG. 8. Cross section for $\gamma\gamma \to \pi^0\pi^0$ as a function of W for $W < 0.7$ GeV and $|\cos\theta^*| < 0.8$. Also shown is the prediction (solid line) from the model in Ref. 8.

Compare cross sections for η and $\pi^0\pi^0$ production through the Primakoff process

$$\Delta\sigma_{\eta\to\pi\pi} \equiv \frac{d^2\sigma_P}{d\Omega\Delta W_\eta} = \Gamma_{\gamma\gamma}\frac{8\alpha Z^2\beta^3E^4}{m_\eta^3Q^4}F^2\sin^2\theta_\eta\frac{BR}{\Delta W_\eta}$$

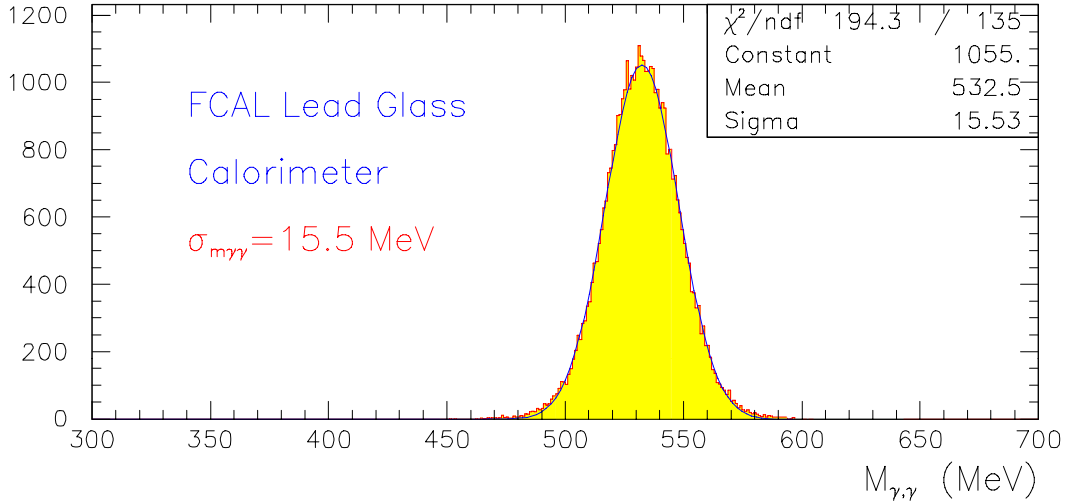
$$\Delta\sigma_{\pi\pi} \equiv \frac{d^2\sigma_{\pi\pi}}{d\Omega dW_{\pi\pi}} = \frac{\alpha Z^2\beta^3E^4}{\pi^2W_{\pi\pi}^2Q^4}\left|F(Q)\right|^2\sin^2\theta_{\pi\pi}K_\pi^{cm}\sigma_{\gamma\gamma\to\pi\pi}$$

$$\frac{S}{N} = \frac{\Delta\sigma_{\eta\to\pi\pi}}{\Delta\sigma_{\pi\pi}} = \frac{8\pi^2\Gamma_{\gamma\gamma}}{m_\eta K_\pi^{cm}\sigma_{\gamma\gamma\to\pi\pi}}\frac{BR}{\Delta W_\eta}$$

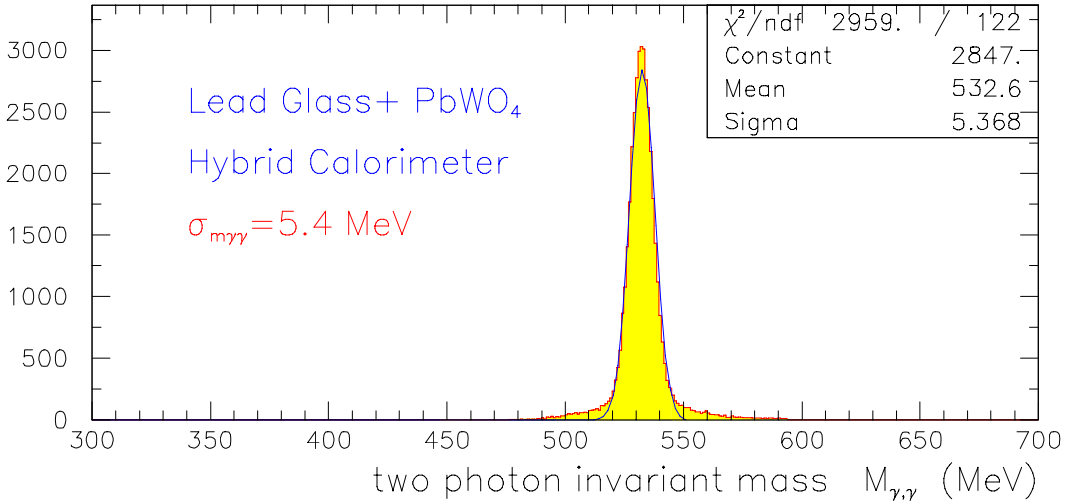
$$\frac{S}{N} \approx 1.3\times10^4\,MeV\frac{BR}{\Delta W_\eta}$$

Experimental Resolutions (inv. mass)

FCAL with all Pb-glass



FCAL with Pb-glass and PbWO4 crystal insertion (75x75 blocks (150x150 cm^2)



$$\frac{S}{N} \approx 1.3 \times 10^4 \, MeV \, \frac{BR}{\Delta W_\eta}$$

Take S/N ≈ ½ as an acceptable signal to background ratio.

Assume that we can achieve $\Delta W_\eta \approx 10$ MeV for the experimental resolution

BR ≈ 4×10^{-4}

This is only as good as the present experimental limit on $\eta \rightarrow \pi^0 \pi^0$

Conclusions:

1. It will not be possible to obtain a significant reduction (1/10th) in the $\eta \rightarrow \pi^0\pi^0$ BR through η Primakoff production
2. Will need to look at inclusive production in $\gamma p \rightarrow \eta X$ interactions

- Defending this measurement will not be easy. What are the backgrounds? How do you know you've accounted for all of them?