π^0 **Lifetime Extraction from** ^{12}**C and** ^{208}**Pb**

Dustin McNulty
MIT/UMass
mcnulty@jlab.org

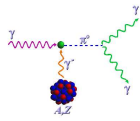September 26, 2008

1
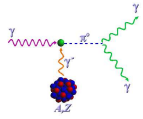
π^0 Lifetime Extraction from ^{12}C and ^{208}Pb

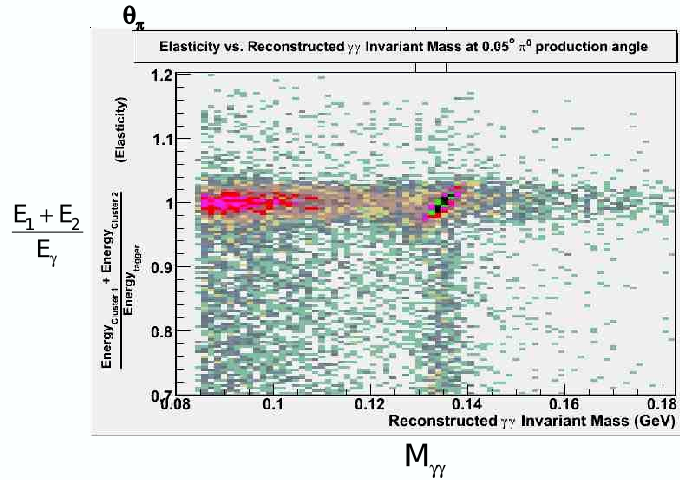- Final results in hand

  What's been done:

  - Employed latest incoherent π^0 production models
  - Employed latest Coulomb and Strong form factors
  - Explored full range of Strong FF shadowing parameters
  - Incorp. predicted phase angle together with empirical phase
  - Included effects of $\omega \to \pi^0 \gamma$ at yield level
  - All theoretical fit shapes smeared with experimental resolutions

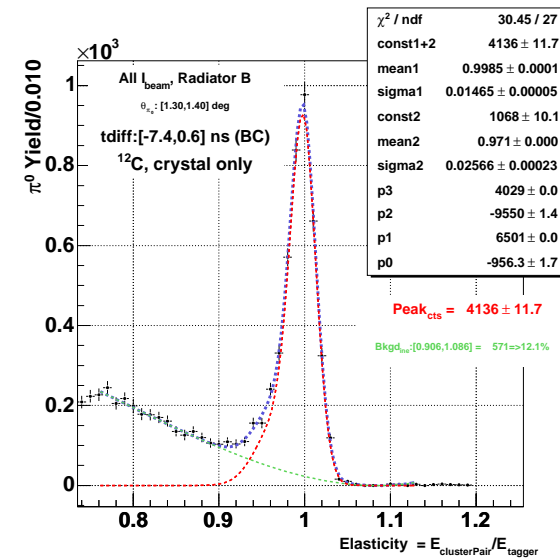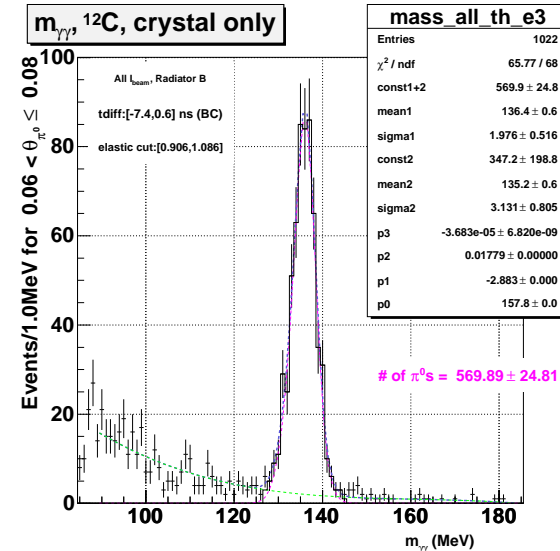| target	$\Gamma_{\gamma\gamma}$	fit (stat) err	model err	syst err	total err
C: av	7.92	0.15(2.0%)	0.10(1.3%)	0.16(2.0%)	0.24(3.1%)
Pb:av	8.10	0.17(2.1%)	0.10(1.3%)	0.16(2.0%)	0.26(3.2%)
Pb+C:av	8.01	0.12(1.5%)	0.10(1.3%)	0.16(2.0%)	0.22(2.8%)

Yield Analysis
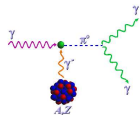
Extracting Elastic Pion Yields versus θ_π

Elasticity vs. Reconstructed $\gamma\gamma$ Invariant Mass at 0.05° π^0 production angle

$\frac{E_1 + E_2}{E_\gamma}$

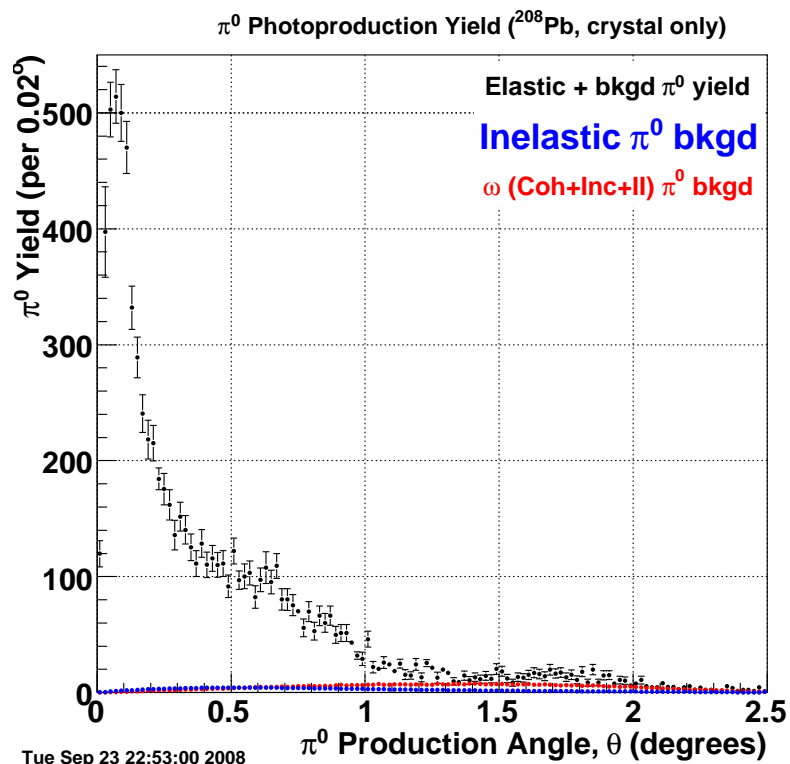$M_{\gamma\gamma}$

$m_{\gamma\gamma}$, ^{12}C, crystal only

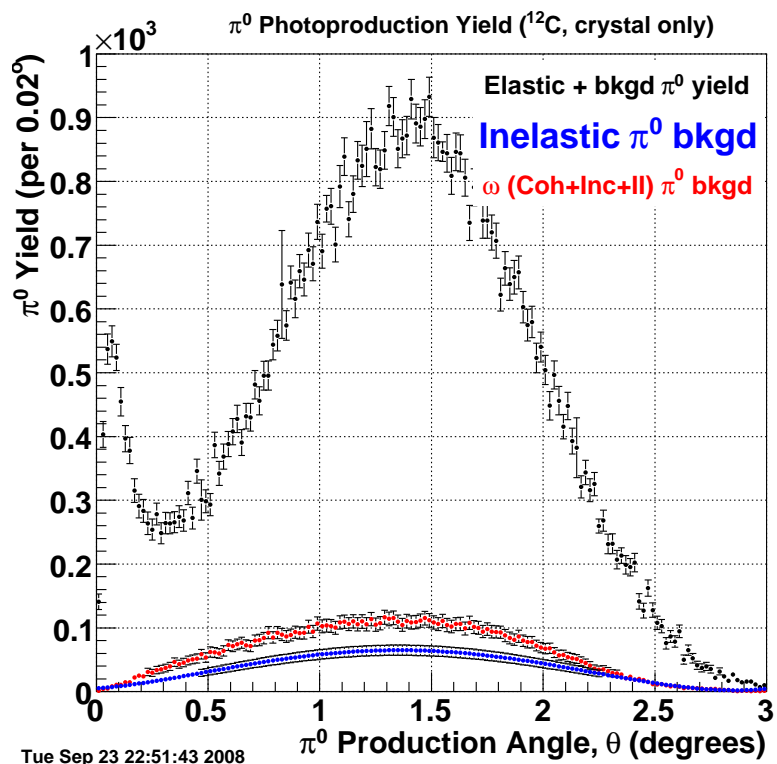- Straight forward yield analysis
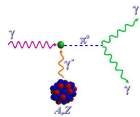- –Cuts on timing, invariant mass, and elasticity

- Backgrounds subtracted:
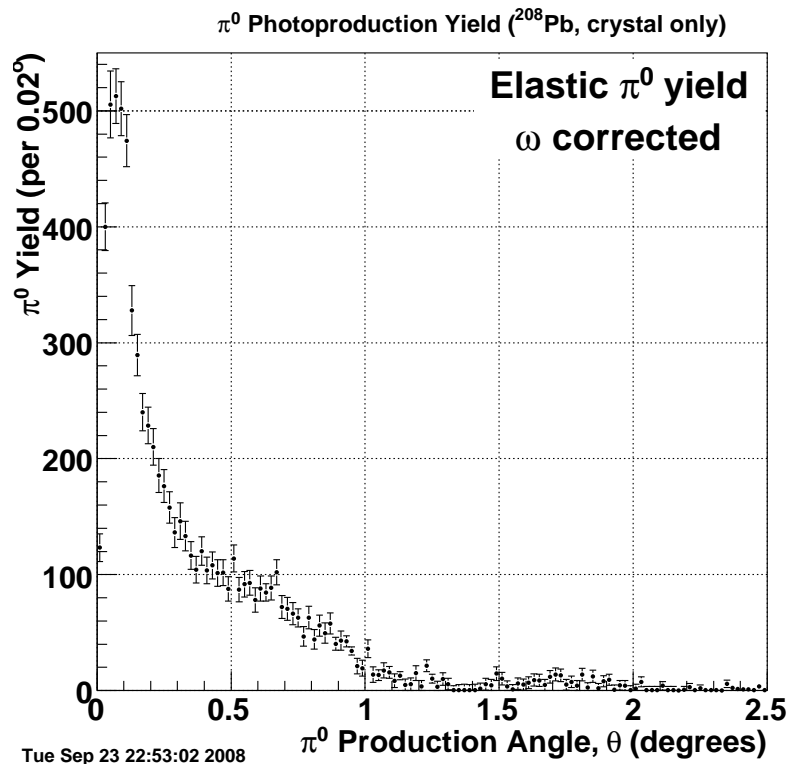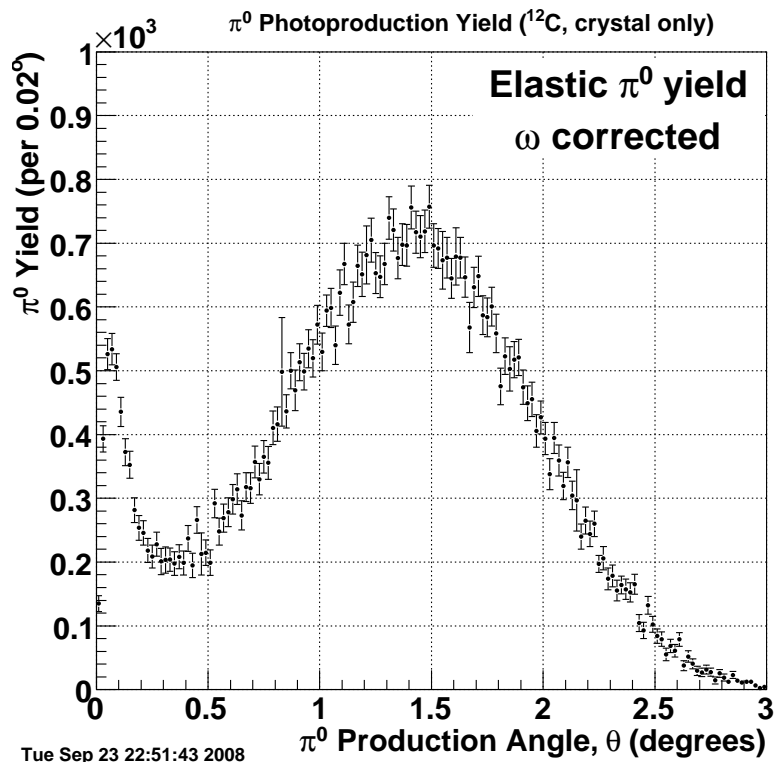- –timing accidentals
- –inelastic π^0's
- –π^0's from ω decay

Yields with Backgrounds

π^0 Photoproduction Yield (^{12}C, crystal only)

Elastic + bkgd π^0 yield
Inelastic π^0 bkgd
ω (Coh+Inc+II) π^0 bkgd

π^0 Yield (per 0.02°)

π^0 Production Angle, θ (degrees)

Tue Sep 23 22:51:43 2008

π^0 Photoproduction Yield (^{208}Pb, crystal only)

Elastic + bkgd π^0 yield
Inelastic π^0 bkgd
ω (Coh+Inc+II) π^0 bkgd

π^0 Yield (per 0.02°)

π^0 Production Angle, θ (degrees)

Tue Sep 23 22:53:00 2008

Final Yields

π⁰ Photoproduction Yield (¹²C, crystal only)

Elastic π^0 yield
ω corrected

Tue Sep 23 22:51:43 2008

π⁰ Photoproduction Yield (²⁰⁸Pb, crystal only)

Elastic π^0 yield
ω corrected

Tue Sep 23 22:53:02 2008
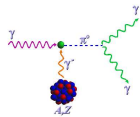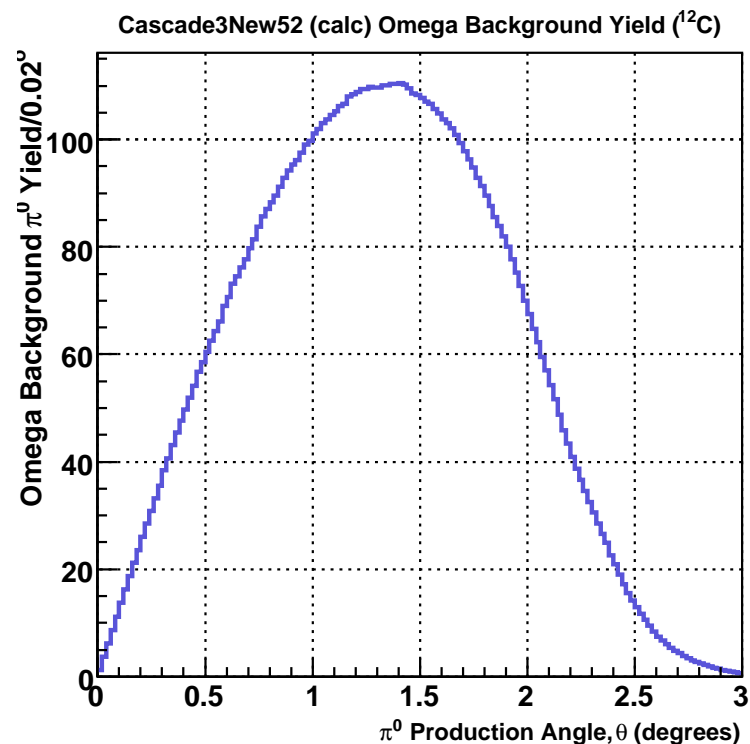
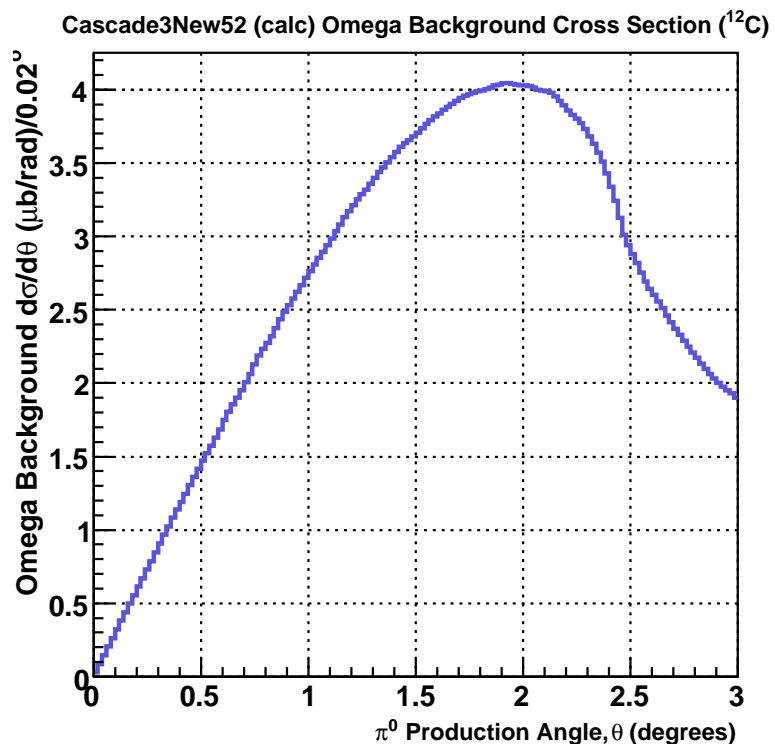# The $\omega \to \pi^0\gamma$ Background Correction

- $d\sigma/d\theta_{\pi^0}$ for $\omega \to \pi^0\gamma$ taken from T. Rodrigues and implemented in 2 ways

- 1st method: Add omega and incoherent cross sections and use this shape for fitting the data (instead of just incoherent term)

- 2nd method: Convert ω cross section into absolute yield and explicitely subtract it from experimental yield

ω Cross Section and Yield for ^{12}C

Cascade3New52 (calc) Omega Background Cross Section (^{12}C)

Cascade3New52 (calc) Omega Background Yield (^{12}C)

ω Cross Section and Yield for ^{208}Pb

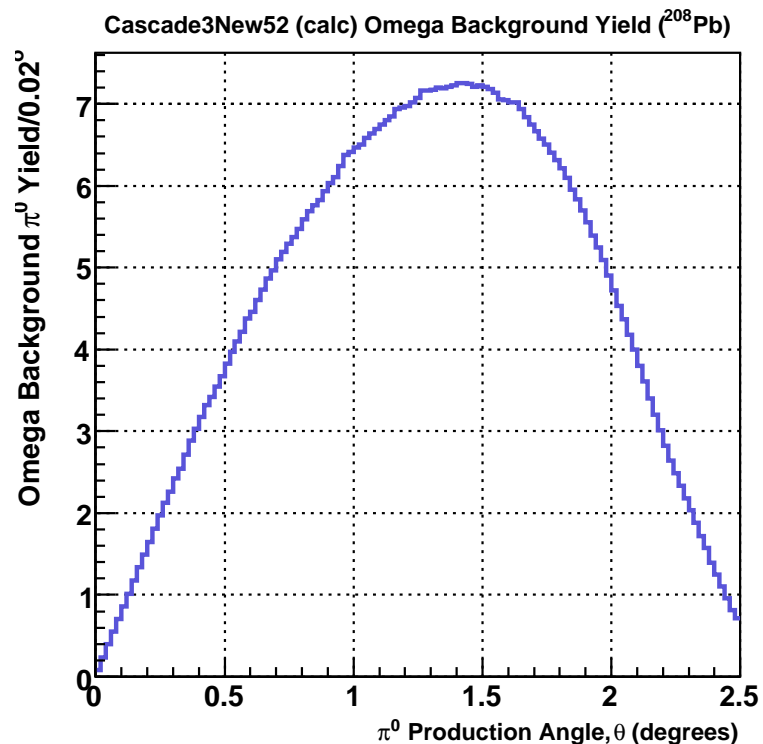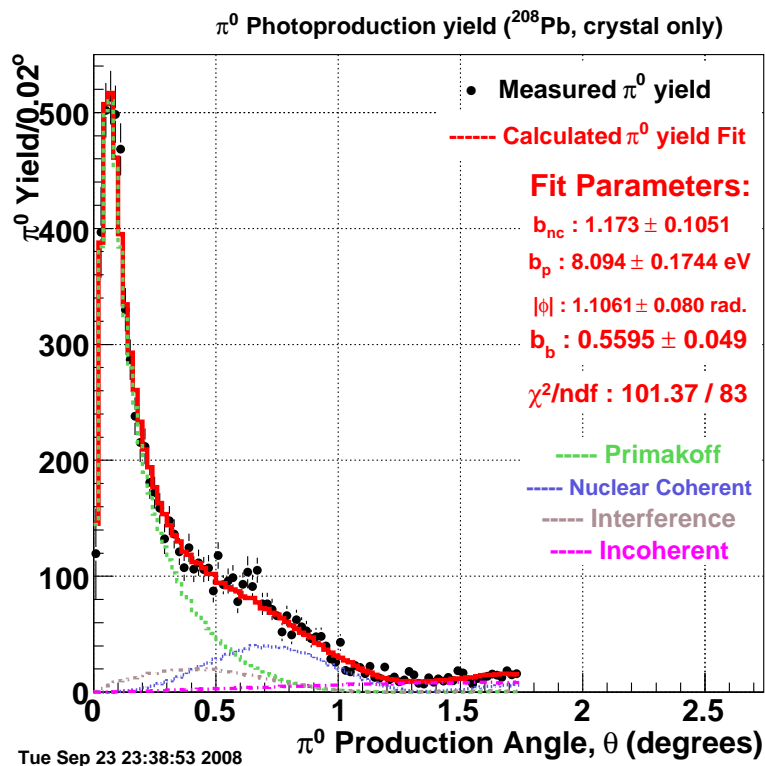**Cascade3New52 (calc) Omega Background Cross Section (^{208}Pb)**
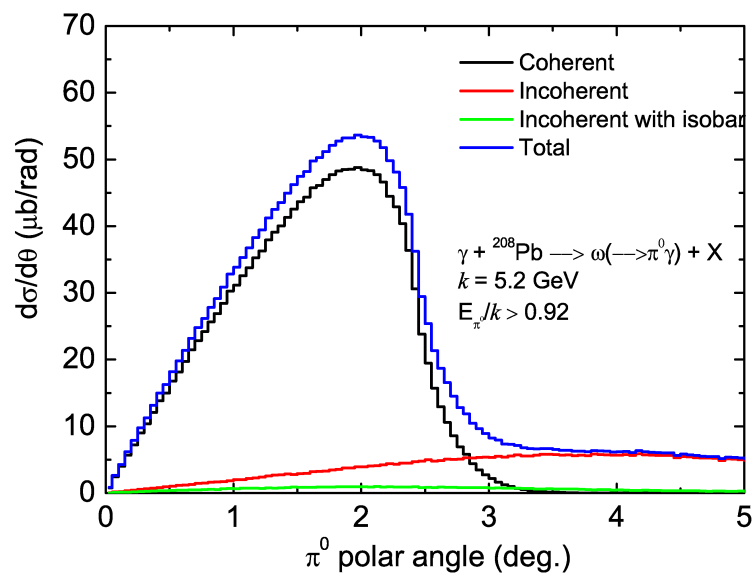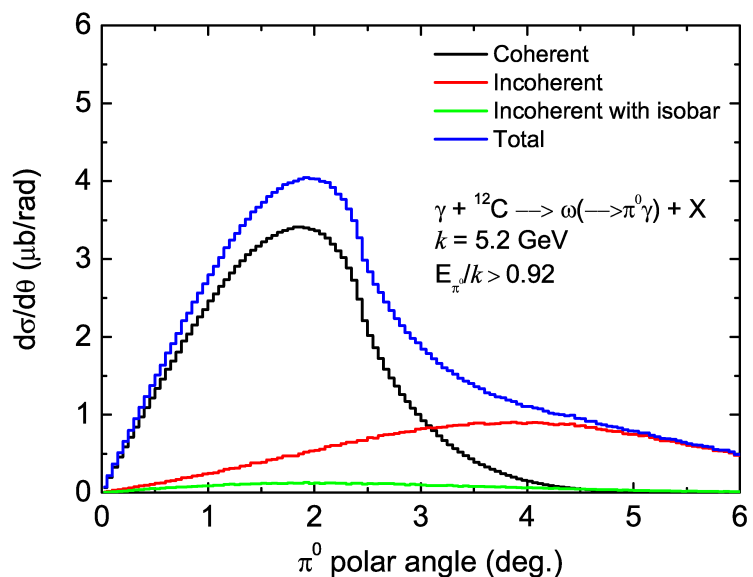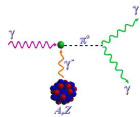
Cascade3New52 (calc) Omega Background Yield (^{208}Pb)
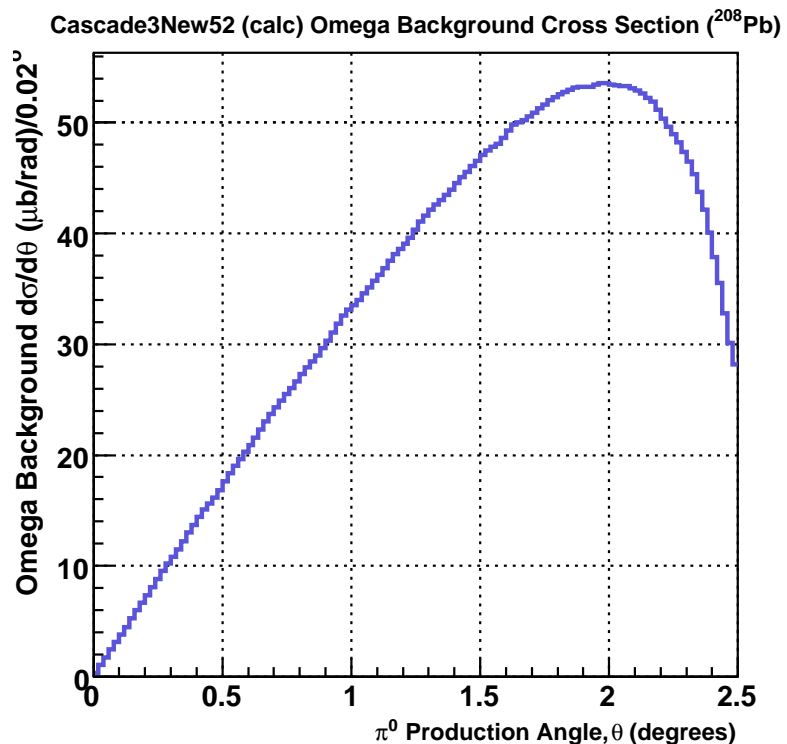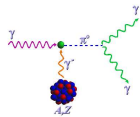
Sample Yield Fits Using ω + Inc Shape (1ˢᵗ Method)

$$\text{Rinc:}\psi = \tfrac{1}{4}\text{:om-sig}$$

π⁰ Photoproduction yield (¹²C, crystal only)

- **Measured π⁰ yield**
- ----- **Calculated π⁰ yield Fit**

Fit Parameters:
b_{nc} : 1.960 ± 0.0362
b_p : 7.921 ± 0.1525 eV
$|\phi|$: 0.6572 ± 0.062 rad.
b_b : 0.5811 ± 0.045

χ^2/ndf : 170.67 / 121

- ----- **Primakoff**
- ----- **Nuclear Coherent**
- ----- **Interference**
- ----- **Incoherent**

Tue Sep 23 23:31:53 2008

π⁰ Photoproduction yield (²⁰⁸Pb, crystal only)

- **Measured π⁰ yield**
- ----- **Calculated π⁰ yield Fit**

Fit Parameters:
b_{nc} : 1.173 ± 0.1051
b_p : 8.094 ± 0.1744 eV
$|\phi|$: 1.1061 ± 0.080 rad.
b_b : 0.5595 ± 0.049

χ^2/ndf : 101.37 / 83

- ----- **Primakoff**
- ----- **Nuclear Coherent**
- ----- **Interference**
- ----- **Incoherent**

Tue Sep 23 23:38:53 2008

Sample Fits Using ω-Corrected Yield (2nd Method)

Rinc:$\psi = \frac{1}{4}$:omb

π^0 Photoproduction yield (^{12}C, crystal only)

- Measured π^0 yield
- ----- Calculated π^0 yield Fit

Fit Parameters:
b_{nc} : 1.791 ± 0.0370
b_p : 7.926 ± 0.1542 eV
$|\phi|$: 0.9944 ± 0.047 rad.
b_b : 0.4708 ± 0.050
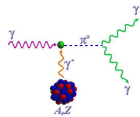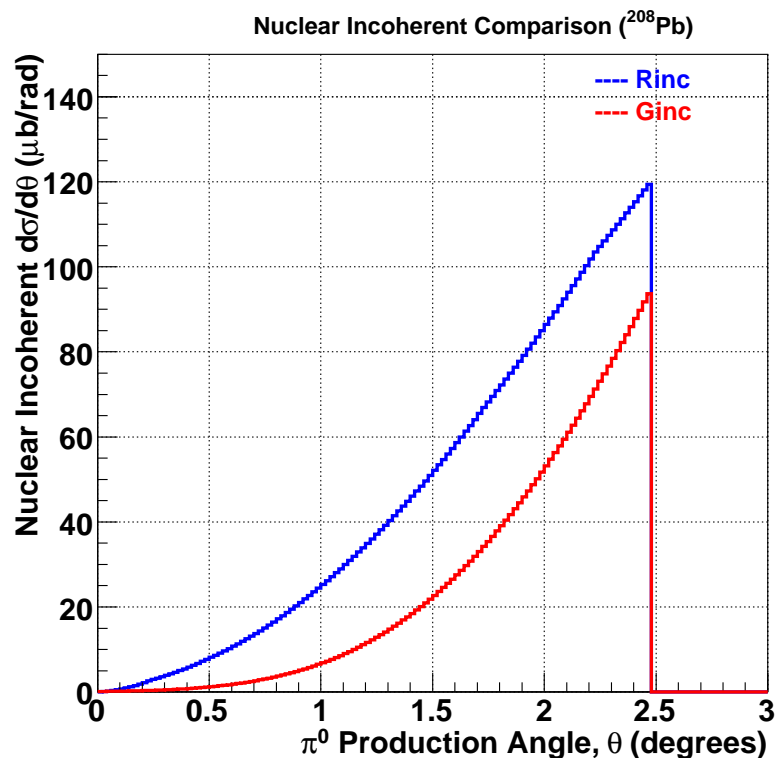
χ^2/ndf : 153.75 / 121

- ----- Primakoff
- ----- Nuclear Coherent
- ----- Interference
- ----- Incoherent

Tue Sep 23 21:46:55 2008

π^0 **Production Angle, θ (degrees)**

π^0 Photoproduction yield (^{208}Pb, crystal only)

- Measured π^0 yield
- ----- Calculated π^0 yield Fit

Fit Parameters:
b_{nc} : 1.207 ± 0.1137
b_p : 8.108 ± 0.1764 eV
$|\phi|$: 1.1374 ± 0.080 rad.
b_b : 0.1319 ± 0.123

χ^2/ndf : 79.98 / 83

- ----- Primakoff
- ----- Nuclear Coherent
- ----- Interference
- ----- Incoherent

Tue Sep 23 21:47:12 2008

π^0 **Production Angle, θ (degrees)**

Incoherent Cross Sections

$\Gamma_{\gamma\gamma}$ **Fit Summmary:** ^{12}**C**

Label	$\Gamma_{\gamma\gamma}\pm$ fit err in eV (fit χ^2)		
	Standard	1$^{\text{st}}$ Method	2$^{\text{nd}}$ Method
C:Rinc:$\psi = 0$	7.85 ± 0.15 (1.29)	7.88 ± 0.15 (1.48)	7.91 ± 0.15 (1.32)
C:Rinc:$\psi = \frac{1}{4}$	7.84 ± 0.15 (1.41)	7.92 ± 0.15 (1.41)	7.93 ± 0.15 (1.27)
C:Rinc:$\psi = \frac{1}{2}$	7.88 ± 0.15 (1.41)	7.91 ± 0.15 (1.41)	7.95 ± 0.16 (1.31)
C:Rinc:$\psi = 1$	8.05 ± 0.15 (1.44)	7.94 ± 0.15 (1.25)	7.99 ± 0.16 (1.27)
C:Ginc:$\psi = 0$	7.85 ± 0.15 (1.49)	N/A	7.93 ± 0.15 (1.24)
C:Ginc:$\psi = \frac{1}{4}$	7.84 ± 0.15 (1.37)	N/A	7.92 ± 0.15 (1.27)
C:Ginc:$\psi = \frac{1}{2}$	7.89 ± 0.15 (1.53)	N/A	7.90 ± 0.16 (1.28)
C:Ginc:$\psi = 1$	7.88 ± 0.15 (1.48)	N/A	7.94 ± 0.16 (1.25)
Average	7.88 ± 0.15 (1.43)	7.91 ± 0.15 (1.39)	7.93 ± 0.16 (1.29)
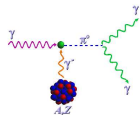
$\Gamma_{\gamma\gamma}$ Fit Summmary: ^{208}Pb

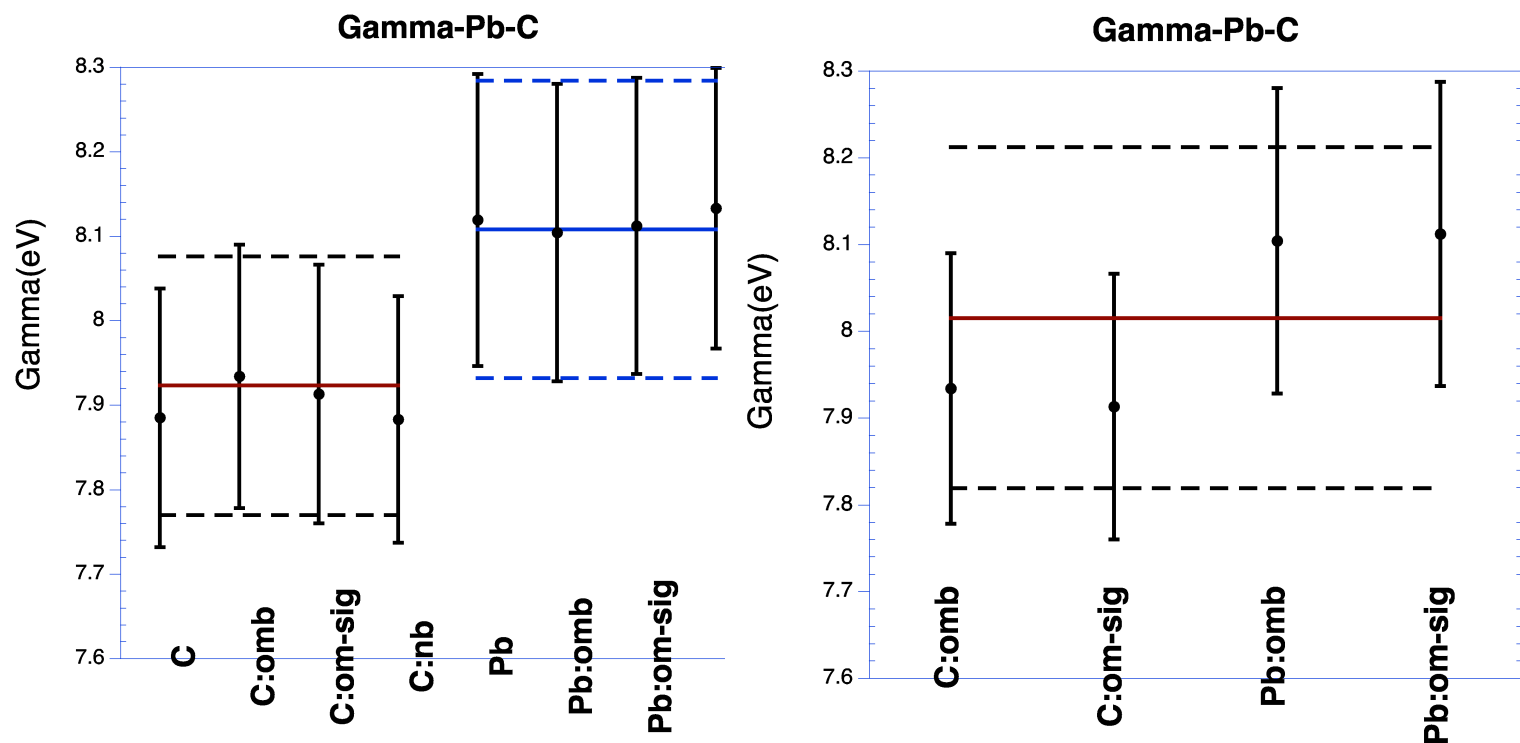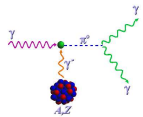| Label	$\Gamma_{\gamma\gamma}\pm$ fit err in eV (fit χ^2)		
	Standard	1st Method	2nd Method
Pb:Rinc:$\psi = 0$	8.04 ± 0.17 (1.26)	8.06 ± 0.17 (1.20)	8.08 ± 0.18 (0.98)
Pb:Rinc:$\psi = \frac{1}{4}$	8.11 ± 0.18 (1.25)	8.09 ± 0.17 (1.22)	8.11 ± 0.18 (1.02)
Pb:Rinc:$\psi = \frac{1}{2}$	8.09 ± 0.17 (1.21)	8.07 ± 0.18 (1.20)	8.09 ± 0.18 (0.96)
Pb:Rinc:$\psi = 1$	8.18 ± 0.18 (1.24)	8.17 ± 0.17 (1.26)	8.17 ± 0.18 (0 95)
Pb:Ginc:$\psi = 0$	8.08 ± 0.17 (1.29)	N/A	8.06 ± 0.17 (0.98)
Pb:Ginc:$\psi = \frac{1}{4}$	8.09 ± 0.17 (1.30)	N/A	8.05 ± 0.18 (0.96)
Pb:Ginc:$\psi = \frac{1}{2}$	8.13 ± 0.17 (1.33)	N/A	8.10 ± 0.18 (0.96)
Pb:Ginc:$\psi = 1$	8.19 ± 0.18 (1.45)	N/A	8.15 ± 0.18 (0.92)
Average	8.11 ± 0.17 (1.29)	8.10 ± 0.17 (1.22)	8.10 ± 0.16 (0.97)

% Change in $\Gamma_{\gamma\gamma}$ versus Shadowing Parameter ψ
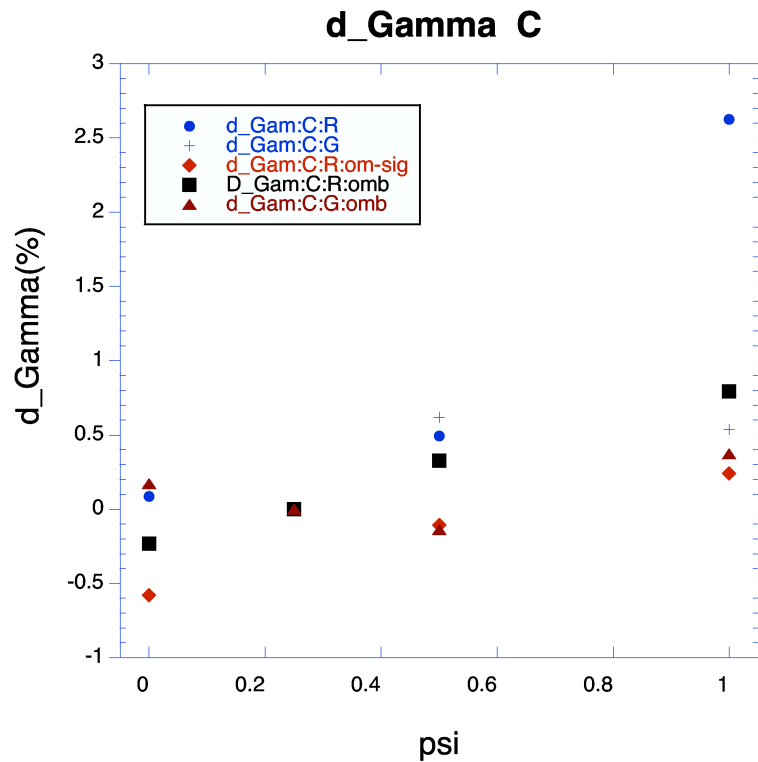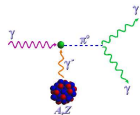
$\Gamma_{\gamma\gamma}$ **Results**
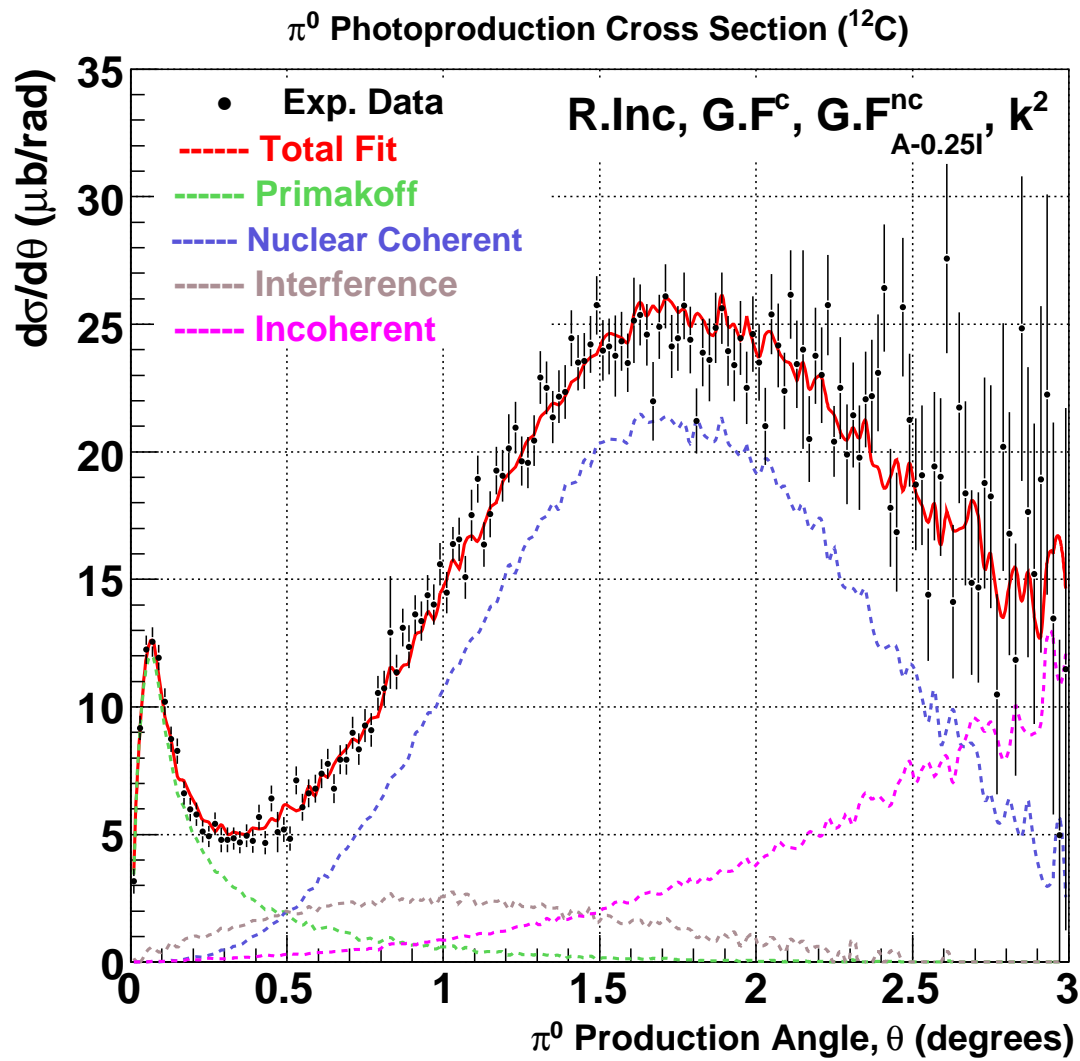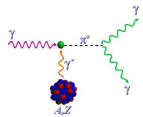
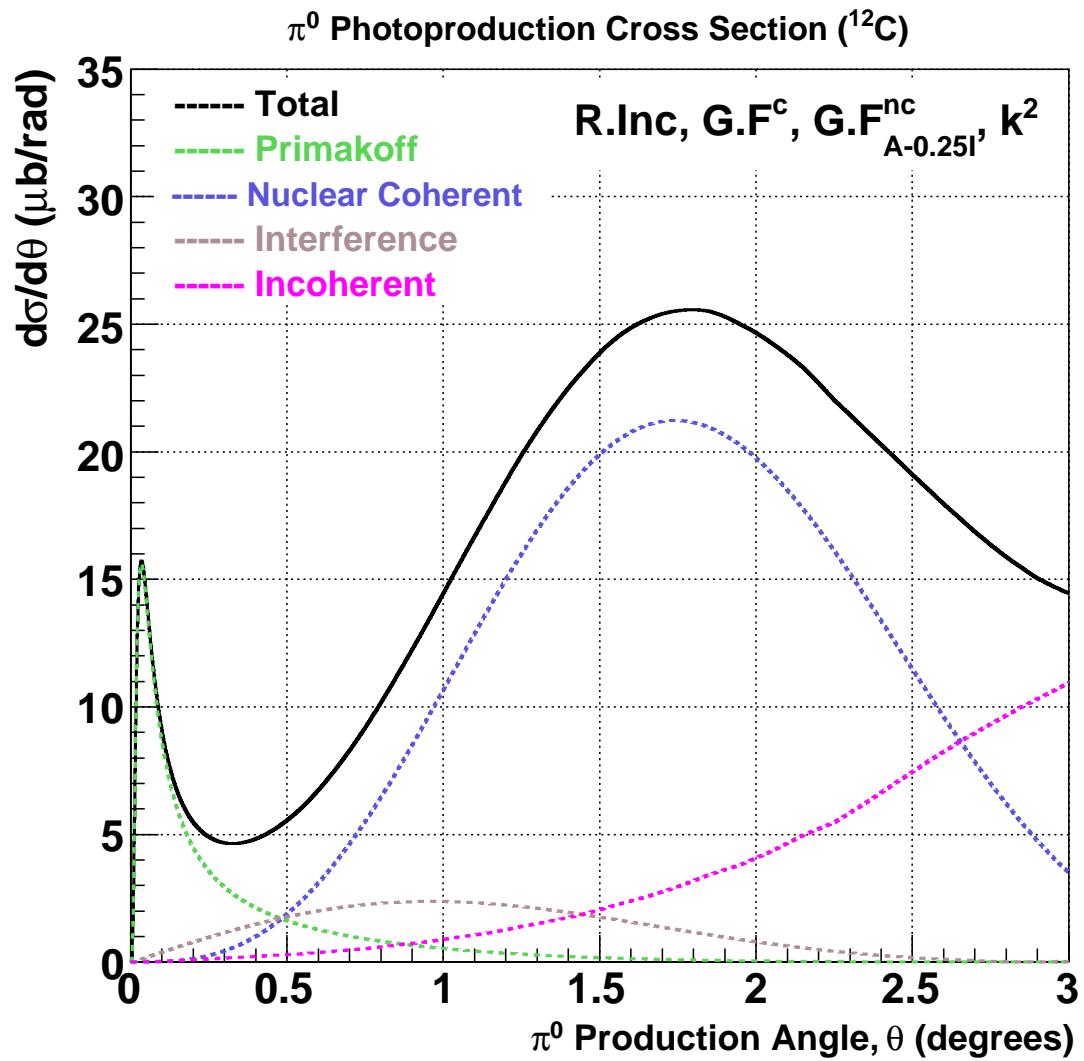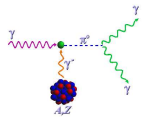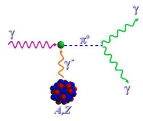# $\gamma(^{12}\text{C, X})\pi^0$ Cross Section

π^0 Photoproduction Cross Section (^{12}C)

$\gamma(^{12}C, X)\pi^0$ Cross Section (Un-smeared)

π^0 Photoproduction Cross Section (^{12}C)

R.Inc, G.F^c, G.F$^{nc}_{A-0.25I'}$, k^2

Legend:
- ------ Total
- ------ Primakoff
- ------ Nuclear Coherent
- ------ Interference
- ------ Incoherent

y-axis: $d\sigma/d\theta$ (μb/rad)

x-axis: π^0 Production Angle, θ (degrees)

$\gamma(^{12}C, X)\pi^0$ Cross Section (Group Comparison
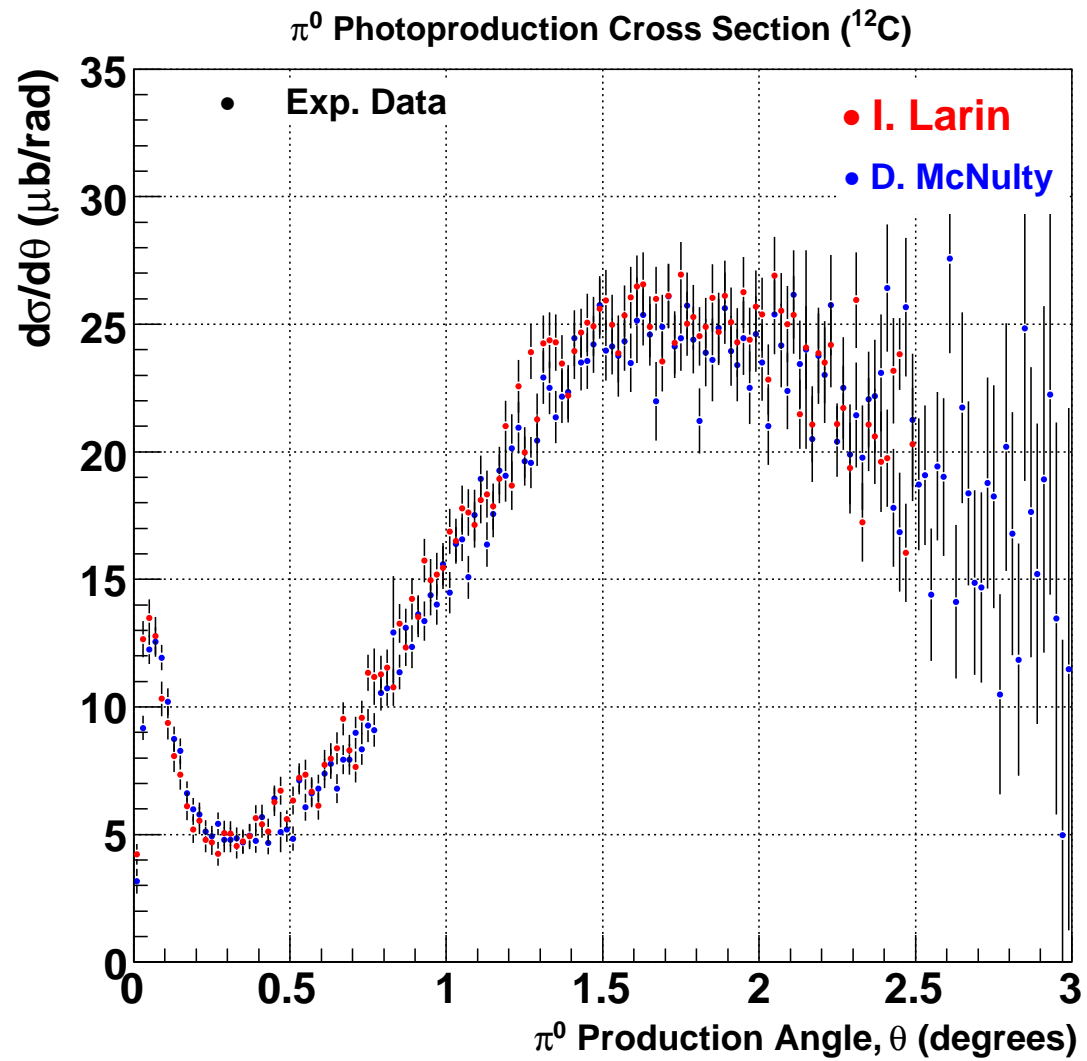
$\gamma(^{208}\text{Pb, X})\pi^0$ **Cross Section**
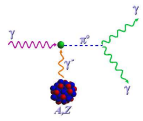
$\gamma(^{208}\mathbf{Pb}, \mathbf{X})\pi^0$ Cross Section (Un-smeared)

π^0 Photoproduction Cross Section (^{208}Pb)

Legend:
- ------ Total
- ------ Primakoff
- ------ Nuclear Coherent
- ------ Interference
- ------ Incoherent

R.Inc, G.F^c, G.F$^{nc}_{A-0.25I'}$, k^2

y-axis: $d\sigma/d\theta$ (μb/rad), $\times 10^3$
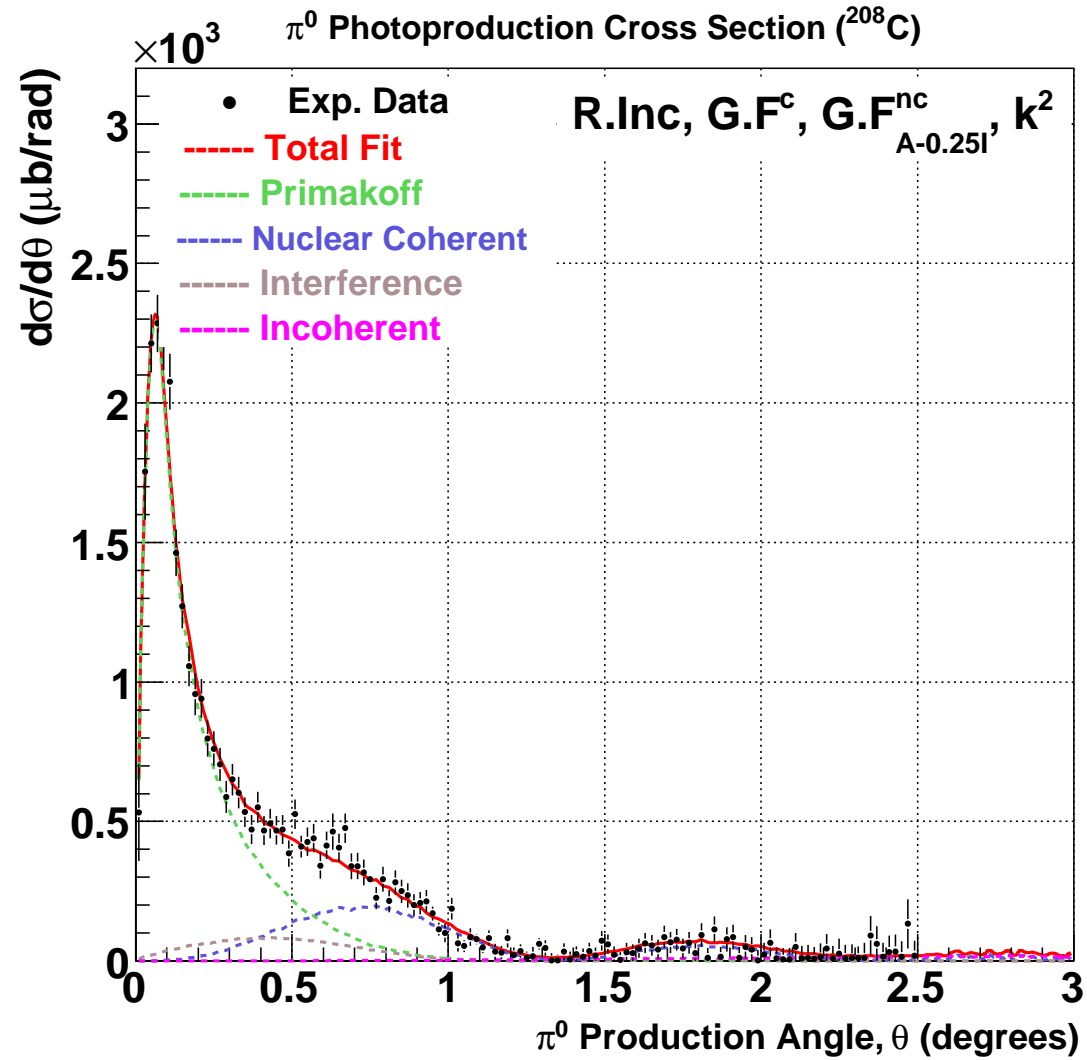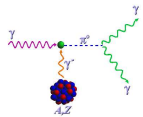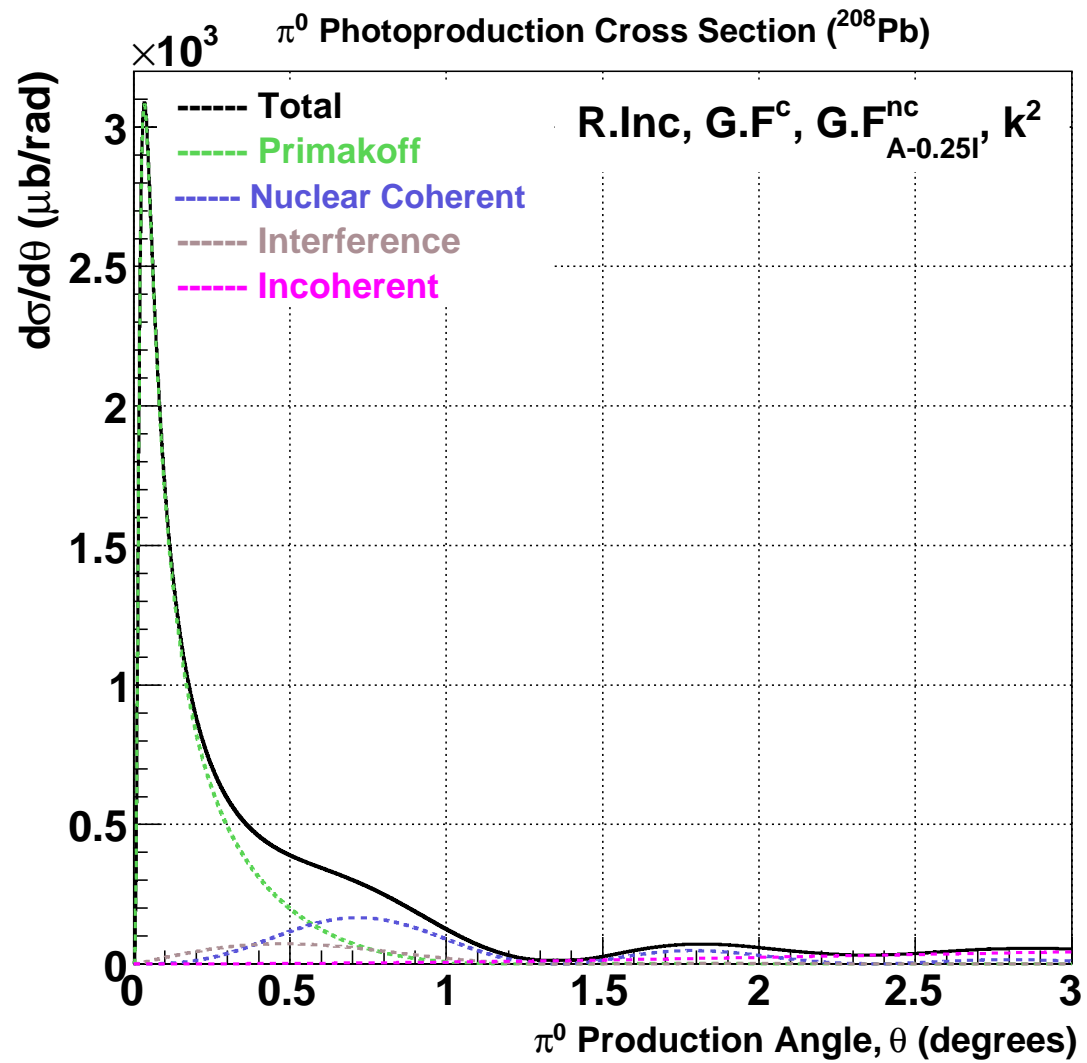
x-axis: π^0 Production Angle, θ (degrees)

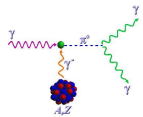# $\gamma(^{208}\text{Pb}, \text{X})\pi^0$ Cross Section (Group Comparison)

π^0 Photoproduction Cross Section (^{208}Pb)

- I. Larin
- D. McNulty

dσ/dθ (μb/rad)

π^0 Production Angle, θ (degrees)
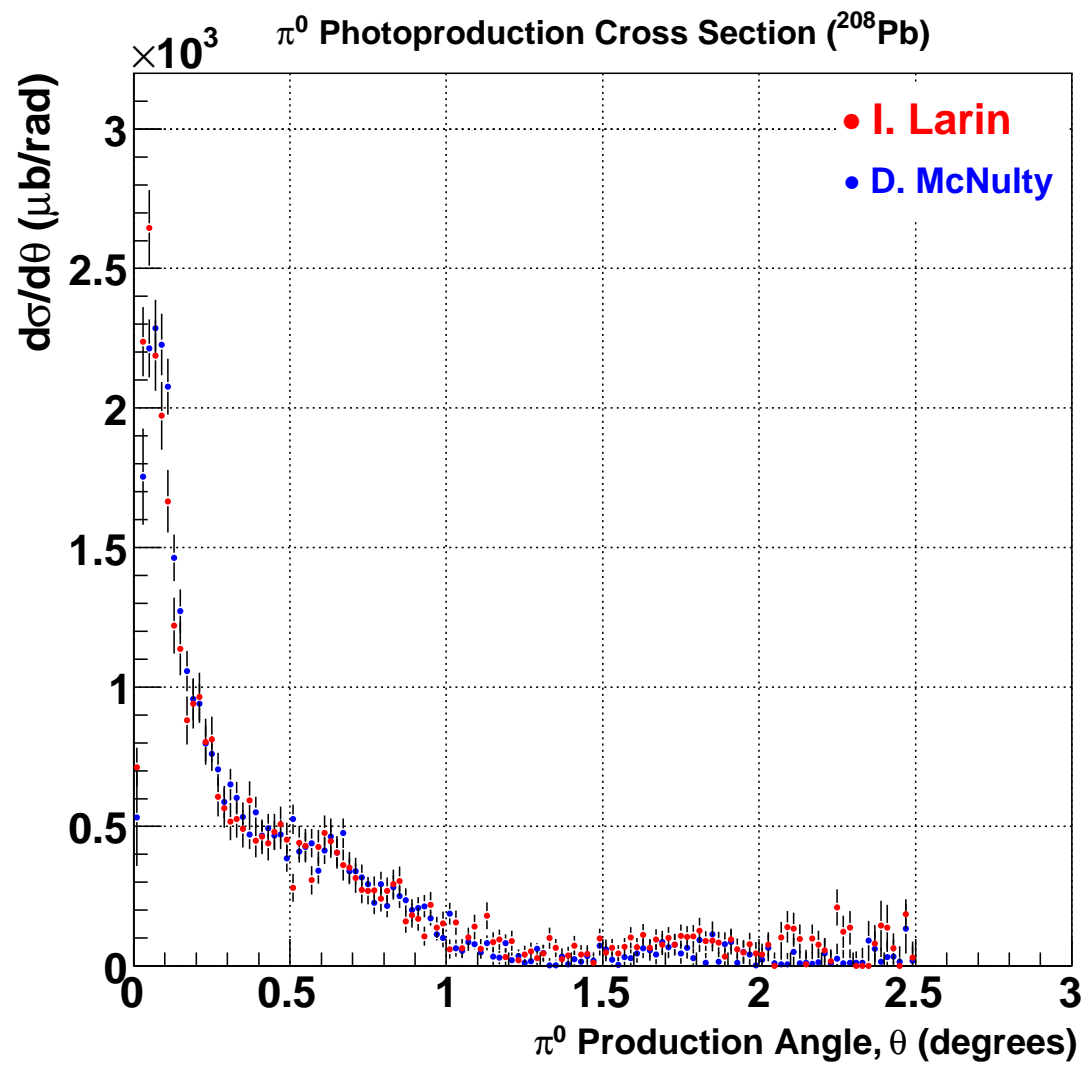
Summary and Future Work

- All past comments and requests have been addressed

- $\Gamma_{\gamma\gamma}$ fit results very stable under various yield Bkgd corrections and theoretical input shapes!

target	$\Gamma_{\gamma\gamma}$	fit (stat) err	model err	syst err	total err
C: av	7.92	0.15(2.0%)	0.10(1.3%)	0.16(2.0%)	0.24(3.1%)
Pb:av	8.10	0.17(2.1%)	0.10(1.3%)	0.16(2.0%)	0.26(3.2%)
Pb+C:av	8.01	0.12(1.5%)	0.10(1.3%)	0.16(2.0%)	0.22(2.8%)

To make the final report we need to:

- Re-check our results and finish the write-up

- Address questions and issues brought up at this meeting as well as comments from analysis note reviewers