$(\gamma, pp)$ reactions at Mainz

STATUS OF COHERENT BREMSSTRAHLUNG

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Motivation for ($\gamma$,pp) Experiment
Scope of the Measurement

Coherent Bremsstrahlung Status
Preliminary Data Analysis
Next Analysis Steps
Motivation for (γ,pp) Reactions

- (γ,pp) reactions proceed via Δ-currents and Short Range Correlations.

- MEC are suppressed and FSI effects are expected to be small, simplifying the interpretation of measurements.
Differential Cross Section

\[ \frac{d\sigma}{d\Omega}(\theta, \phi) = \frac{d\sigma}{d\Omega}(\theta)[1 + P\Sigma \cos(2\phi)] \]

where \( P \) is degree of linear photon polarisation

- Photon Asymmetry \( \Sigma \) provides information on the difference between the parallel and perpendicular responses.
- This allows a more detailed comparison with theory and provides an additional handle to separate the contributing mechanisms.
• Pronounced structure in $\Sigma$ at low $E_m$ in ($\gamma$,pp) channel

• Distinct differences observed between ($\gamma$,pp) and ($\gamma$,pn)

• At low $E_m$ $\Sigma$ is larger in ($\gamma$,pp) than ($\gamma$,pn)

=> Direct process, no charge exchange FSI
• Comparison with unfactorised calculations (Ryckebusch et al.) including central and tensor SRC

• Theory fails to properly account for dominant Δ-current parallel and perpendicular contributions

• However, previous (γ,pp) data had poor statistical accuracy, limited $E_\gamma$ (180-340 MeV) and $\theta_p$ coverage (50°-130°)

• Need for better measurements over a wider range of $E_\gamma$ and $\theta_p$
• Fit experimental data with \( anb \) to calculate photon polarisation

• Enhancement spectrum from 1\(^{\text{st}}\) goniometer setting: Coherent edge at 300 MeV

• Anb does not fit enhancement due to instability with incident beam

• Obtain \( P_{\text{ave}} \sim 50\% \) for \( E_\gamma = 200-300 \text{ MeV} \)
• $\Sigma$ for coherent $\pi^0$ photoproduction known to equal 1
  • Conservation of helicity
  • Independent measurement of beam polarisation can be extracted from clean coherent signal

• High xsec - Clean asymmetry on a run by bun basis

• $P \Sigma \sim 0.62$ for 1$^{st}$ setting
  • $E_\gamma = 200$-300 MeV
Selection of $^{12}\text{C}(\gamma,\pi^0)$ events

- $\pi^0$ meson - produced with ~equal probability on protons AND neutrons.

- Select reactions which leave nucleus in ground state

Reconstruct $\pi^0$ from $\pi^0 \rightarrow 2\gamma$ decay

\[ \Delta E_\pi = E_{\pi}^{\text{cm}}(E_\gamma) - E_{\pi}^{\text{cm}}(\gamma_1\gamma_2) \]

- Coherent peak clearly visible around 0MeV

- Quasifree and incoherent events are shifted to higher missing energies

- Cut on $\Theta_\pi < 45^\circ$ enhances coherent contribution over background processes (xsec forward focussed_
\(^{12}\text{C}(\gamma, \pi^0)\) provides a reliable method to extract photon polarisation

- This extraction succeeds where an \textit{a}n \textit{b} fit to tagger enhancement spectra fails
- i.e. When the incident MAMI beam is unstable and the coherent peak shifts along the tagger during the beamtime

\[ \text{Photon Energy (MeV)} \]

\[ \text{Enhancement} \]

\[ \text{Polarisation} \]

\[ E_\gamma \]

\[ \text{1}\text{st goniometer setting} \]

\[ \text{2}\text{nd goniometer setting (misalignment between beam and collimator)} \]
- Geant4 simulation with phase space generate 'fires' protons from within the target dimensions
- Calculate the energy loss as protons traverse through the Ball (as a function of energy and angle)

- A second correction is required to convert the energy into MeV (rather than “γ tuned” MeV)
- Calibrate proton response in the ball using the kinematically overdetermined p(γ, π⁰) reaction
- Secondary correction depends on the measured proton energy
- independent of angle,
- Define correction factor:
  \[ C = \frac{E_{p}^{\text{Diff}}}{E_{p}^{\text{Meas}}} \]
- To correct for proton response
  \[ E_{p} = E_{p}^{\text{meas}} \times C + E_{p}^{\text{meas}} \]
- Correction factor determined for each \( E_{p}^{\text{meas}} \) slice
- Can use this information to calibrate missing energy for \(^{12}\text{C}(\gamma, pp)\)
Preliminary Results: Missing Energy

- \( E_m = E_\gamma - T_{p1} - T_{p2} - T_{\text{res}} \)
- Missing Energy very much as expected with proton energy resolution
- Measurement agrees with previous PIPTOF analysis
Preliminary Results: Photon Asymmetry

\[ E_m < 40\text{MeV} \]

\[ 40 < E_m < 70\text{MeV} \]
• Preliminary analysis of $\Sigma(\gamma, pp)$ agrees with previous analyses with slight improvement in statistical accuracy
• Work is ongoing on a maximum likelihood technique which aims to reduce the statistical uncertainty further by a factor of $\sim 3$
• Investigation of the angular behavior of $\Sigma$
• Use information from coherent pion analysis to extract $\Sigma$ in region of the second coherent peak:

$$400 < E_\gamma < 500\text{MeV}, \ P_{\text{ave}} \sim 0.2$$