Final saGDH n2 Cross Sections

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Overview

• Finished up/finalized the saGDH nitrogen cross section analysis
• These slides focus on inelastic RC/bin-centering/systematics
  – Total Settings:
    • 2135/ 6 degrees
    • 2845/ 6 degrees
    • 4209/ 6 degrees -> partial spectrum: \( W > 1575 \) GeV
    • 1147/ 9 degrees
    • 2234/ 9 degrees
    • 3319/ 9 degrees
    • 3775/ 9 degrees -> partial spectrum: \( W > 1281 \) GeV
    • 4404/ 9 degrees -> partial spectrum: \( W > 1641 \) GeV
• Two inelastic RC methods depending on whether or not I had a full spectrum to work with
• Two bin-centering methods to compare systematics
Inelastic RC Systematics

- Systematics that carry-over from the elastic tail analysis:
  - Born approximation: 0.8%
  - Higher order virtual photon loops: 0.4%
  - Target radiation: negligible
  - Energy-peaking approximation: 0.1%
  - Choice of external straggling function: 0.2%
  - Soft-photon should be recalculated
  - Total = 1.5%

- New systematics that need to be considered:
  - Angle-peaking approximation
  - Soft-photon correction
  - Method 1 for a full spectrum: Classic unfolding
    - Interpolation from unfolding procedure
    - Variation in input model cross section for lowest energy spectra
  - Method 2 for a partial spectrum: Ratio of unrad and rad Bosted model
    - Model dependence of this method
Angle Peaking Approx

- Did a comparison between full integral and angle peaking approx for inelastic bremsstrahlung
- Took a long time to run (~1 week for full integral for n2)
- Use a fit to contribution vs. $E_p$ to determine systematic for all settings
  - Fit is 2nd order polynomial

n2: 2135 Mev/ 6 degrees

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[Graph showing comparison between Full Integral, Peaking Approx, and No Rad.
Ratio is Peak/Rad
Contribution is difference in total inelastic rad cross section depending on choice of internal brem.]
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So-Photon Correction

• Compare soft-photon term from Mo and Tsai to Guthrie Miller

• Reminder: inelastic RC is two integrals (energy-peaking approx)
  – Each integral (over $E_s$ and $E_p$) has it’s own (similar) soft-photon term

• For $dE_s$:

  MT: \[ \left( \frac{E_s - E_s'}{E_p R} \right)^{b(t_a + t_r)} \left( \frac{E_s - E_s'}{E_s} \right)^{b(t_b + t_r)} \]

• For $dE_p$:

  Miller: \[ \left( \frac{k_1}{E_s} \right)^{b(t_a + t_r)} \left( \frac{k_1'}{E_p} \right)^{b(t_b + t_r)} \]

  MT: \[ \left( \frac{E_p' - E_p}{E_p'} \right)^{b(t_a + t_r)} \left( \frac{R(E_p' - E_p)}{E_s} \right)^{b(t_b + t_r)} \]

• $k_1$ represents the soft-photon energy limit
Soft-Photon Comparison

• Definition of $k_1$ and $k_1'$ is different for $dE_s$ and $dE_p$ (See equation A9)
• Miller gives a range where soft-photon limit is uncertain
  – Use that range to compare value vs. MT value for systematic uncertainty
    \[ k_1 = \min \left( \frac{1}{3}E, \omega \right), \quad k_1' = \min \left( \frac{1}{3}E, \omega' \right). \]

Use standard deviation of the 4 models as the systematic

Do this for every setting and use interpolation to apply it to the data
Method 1: Unfolding

• Next two slides only apply to cross sections where I had a full spectrum and could do unfolding procedure
Interpolation Error

• Take the Bosted model:
  1. Radiate it and then
  2. Unfold it and then
  3. Compare the unfolded result to the unradiated Bosted model

Do this for every setting and use interpolation to apply it to the data.
• Need an input model for lowest energy spectrum -> Use Bosted
• Determine overall scale of model by comparing radiated model to data
  – Take average of (data/model) as scale
  – Use standard deviation to vary input scale to see how it changes the result
  – For 6/9 degree settings use: scale = 0.80 +/- 0.10
Method 2

• Use ratio of Bosted model radiated and unradiated to correct the cross sections where I don’t have a full spectrum to unfold
Bosted Ratio Systematic

• Determine the systematic by applying the Bosted ratio method to data that I was able to unfold

• Comparison of the two gives the systematic
  – Take weighted average (RC_Bosted/RC_Unfold) for each spectrum
    • Weight is 1 over the propagated systematic error on the above ratio
  – Then average each spectrum to get systematic
  – Limit comparison to lowest W of the spectrum I ultimately want to apply this method to
    • 4209 / 6 degrees: W > 1575 -> Sys = 4.7%
    • 3775 / 9 degrees: W > 1281 -> Sys = 6.5%
    • 4404 / 9 degrees: W > 1641 -> Sys = 4.5%
Bin-Centering Correction

• Vince and I each did an independent bin-centering correction

• Vince’s method: [https://userweb.jlab.org/~vasulk/weekly/Apr_2016/cxsns_Apr132016.pdf](https://userweb.jlab.org/~vasulk/weekly/Apr_2016/cxsns_Apr132016.pdf)
  – Uses only data and calculates cross section in 5 mrad bins across the acceptance
  – See slides above for details

• My method:
  – Use Vince’s function for the scattering angle distribution for the acceptance cuts used in the experiment
  – Calculate the Bosted model weighted to the angles given by the acceptance function
  – Take the ratio between the weighted Bosted model and the Bosted model run at the central angle to find the correction

• Both methods estimate the correction to be at the 1-2% level max

• Apply my method to unbin centered data and compare it to Vince’s results

• Note: Vince’s bin-centered results are on a fully radiated cross section
Bin-Centering Comparison

Vince’s Method:

Two methods agree at the 1-2% level. So ignore any systematics from the bin-center correction.

Remove points that cause discontinuity in ratio and use linear interpolation to apply correction to the data.

My Method:

Discontinuity is not physical: Stitching together of the quasi/inelastic contributions in model.
A few more odds and ends

- Use difference method to correct quasi-elastic peak and then ratio method for rest of spectrum in unfolding
  - Helps control systematic error
  - Systematic errors are applied to the RC correction factor and then propagated in the standard fashion

- Use the Bosted model method for bin-centering

- Kept the absolute value of the statistical uncertainty constant
  - Statistical uncertainty on the raw XS is the same as on the Born XS
Final 2135
n2: 2135 Mev/ 6 degrees

\[ \frac{d\sigma}{d\Omega} \text{ (nb/MeV-sr)} \]

- saGDH Born
- Bosted Model

\[ \nu \text{ (MeV)} \]

Sys (nb/MeV-sr)

- Raw XS
- Tail Sub XS
- Born XS

Sys (%)
Final 2845

n2: 2845 Mev/ 6 degrees
Final 4209

n2: 4209 MeV/ 6 degrees
Final 1147

n2: 1147 MeV/9 degrees
Final 2234

n2: 2234 MeV/ 9 degrees

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figures.png}
\caption{Plot showing the distribution of \( \frac{d\sigma}{dE_{\text{lab}}} \) and systatistical uncertainties for different models: saGDH Born, Bosted Model, Raw XS, Tail Sub XS, and Born XS.}
\end{figure}
Final 3775

n2: 3775 MeV/9 degrees
Final 4404

n2: 4404 MeV/9 degrees

- ○ ○ saGDH Born
- --- Bosted Model
Going Forward

• Immediate: Finish up tech-note description of analysis
  – Reworking/filling-out of original technote

• Near future: Work on creating an archive of all the codes I used to do this analysis
  – Plan to do this over a period of time, when I have some down time. No set plan to have it finished by a certain date

• Cross section paper?
  – Potentially depends on He3 unpolarized analysis
  – I think Vince said there is another student working on that?