Helium-4 Elastic Cross Section
Acceptance Scale Factor

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“Empty” runs normalized to experimental cross section, without solid angle acceptance

\[
\sigma_{\text{unscaled}} = \frac{d\sigma_{\text{raw}}}{d\Omega dE'} \Delta \Omega = \frac{ps_1 N}{Q_{\text{tot}} \rho (LT) \varepsilon_{\text{det}}} \frac{1}{\Delta E' \Delta Z}
\]

\( N \) is the yield, the number of scattered electrons
\( e \) is the electron charge

Quantities from MySQL: \( ps_1 \) is the prescale factor, \( Q_{\text{tot}} \) is the total charge, \( \rho \) is the number density of the electron beam, \( LT \) is the livetime, \( \varepsilon_{\text{det}} \) is the product of all detector efficiencies.
\( \Delta \Omega \) is the solid angle acceptance. Toby cross section cut used:

\[-0.005 < \phi < 0.005 \quad \mid \quad -0.01 < \theta < 0.01\]

\( \Delta E' \) is the energy acceptance: 1 MeV bins
\( \Delta Z \) is the target length from Ryan's Tech Note #19

All runs are 2.2 GeV incident energy, 5 T magnetic field, Helium-4 / ‘Empty’ target

Elastic and quasielastic peaks fit, with fake bins to force QE fit to go to zero by 15 MeV

Run 5650 (Longitudinal)
Raw Cross Section vs. Nu (test cuts) no acceptance

Run 5947 (Transverse)
Raw Cross Section vs. Nu (test cuts) no acceptance
Elastic and quasielastic peaks fit, with fake bins to force QE fit to go to zero by 15 MeV

**Run 5650 (Longitudinal)**
Raw Cross Section vs. $\nu$ (test cuts)

<table>
<thead>
<tr>
<th>$E$ (MeV)</th>
<th>$d\sigma_{\text{raw}}/d\Omega dE'$ (nb sr MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4875</td>
<td>10000</td>
</tr>
<tr>
<td>38.42</td>
<td>9000</td>
</tr>
<tr>
<td>8.754</td>
<td>8000</td>
</tr>
</tbody>
</table>

**Run 5947 (Transverse)**
Raw Cross Section vs. $\nu$ (test cuts)

<table>
<thead>
<tr>
<th>$E$ (MeV)</th>
<th>$d\sigma_{\text{raw}}/d\Omega dE'$ (nb sr MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3357</td>
<td>2000</td>
</tr>
<tr>
<td>40.92</td>
<td>1900</td>
</tr>
<tr>
<td>6.213</td>
<td>1800</td>
</tr>
</tbody>
</table>
Elastic peak integrated and radiative corrections applied, compared to Rosenbluth cross section for elastic scattering. Mo and Tsai method used. Formula is lengthy, see image. All quantities defined well in paper with the exception of \( \Delta E \).

\( \Delta E \) defined in separate Tsai paper as length of Landau tail on elastic peak, but there is some guesswork in the cut-off.

\[
\sigma_{\text{Rosenbluth}} = \frac{d\sigma}{d\Omega} = \left( \frac{d\sigma}{d\Omega} \right)_{\text{Mott}} \times \left\{ \frac{G_E^2(Q^2) + \tau G_M^2(Q^2)}{1 + \tau} + 2\tau G_M^2(Q^2) \tan^2 \frac{\theta}{2} \right\}
\]

Helium form factors taken from McCarthy, Sick, and Whitney, where \( G_E = 2F_{\text{ch}} \)

Our scale factor will be:

\[
S = \frac{\sigma_{\text{Rosenbluth}}}{\sigma_{\text{unscaled}}}
\]

1. “Radiative Corrections to Elastic and Inelastic ep and up Scattering”, L. Mo and Y. Tsai, Reviews of Modern Physics 41:1, 1969
3. “Spin Structure of 3He and the Neutron at Low \( Q^2 \); A Measurement of the Extended GDH Integral and the Burkhardt-Cottingham Sum Rule”, K. Slifer, 2004
## Results

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Systematic Error in S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scattering Angle</td>
<td>13.8% (Longitudinal)</td>
</tr>
<tr>
<td></td>
<td>17.9% (Transverse)</td>
</tr>
<tr>
<td>Mo &amp; Tsai ΔE</td>
<td>4%</td>
</tr>
<tr>
<td>Fit Upper Bound</td>
<td>3.6%</td>
</tr>
<tr>
<td>MSW Form Factors</td>
<td>4.5%</td>
</tr>
<tr>
<td>Incident Charge</td>
<td>1%</td>
</tr>
<tr>
<td>Detector Efficiencies</td>
<td>1%</td>
</tr>
<tr>
<td>Total in Quadrature</td>
<td>15.5% (Longitudinal)</td>
</tr>
<tr>
<td></td>
<td>19.3% (Transverse)</td>
</tr>
</tbody>
</table>

Obtained by varying quantity over an appropriate range

By taking average of data uncertainties that yield MSW fit

From MySQL / Ryan

**Longitudinal**

\[ S = 4759.26 \text{ Sr}^{-1} \pm 15.5\% \]

**Transverse**

\[ S = 6173.17 \text{ Sr}^{-1} \pm 19.3\% \]
Scale factor can hopefully be used in place of acceptance for cross sections

$$\sigma_{\text{unscaled}} \cdot S = \sigma_{\text{accept}}$$

This will hopefully give a smaller systematic error to the other cross sections

Cross section still sensitive to $\Delta E$ even with QE Fit forced to zero at a higher $Q^2$

Error dominated by 2% uncertainty in scattering angle

$\chi^2$ for MSW fit is 0.7, error in fit not known or accounted for.