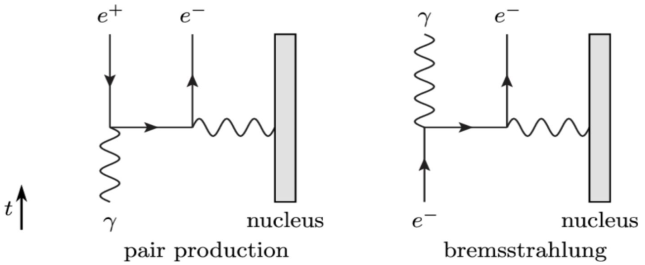
# Bremsstrahlung radiation:

- describes the scattering of electrons off coulombic potentials and by symmetry, $\boldsymbol{e^+e^-}$ pair-production by scattered photons:




*Carlson, Brant. (2009)*

- the dominant energy loss mechanisms for high-energy electrons (~10MeV) and photons, comprises the irreducible QED background for DarkLight
- can be measured straightforwardly by treating positrons as signal events

# Pair production processes:

- (Doublet) Nuclear field scattering / Bethe Heitler (1934):
  - QM-derived quadruply differential cross section, ~$Z^2$
  - Born approximation valid for $2\pi\alpha Z < \beta$

$$\frac{d^4\sigma_A}{d\epsilon_+ d\theta_- d\theta_+ d\phi} = Z^2 \frac{\alpha^3}{2\pi\omega^3\vec{Q}^4} |F_A(\vec{Q}^2) - f_{at}(\vec{Q}^2)|^2 |T|^2$$

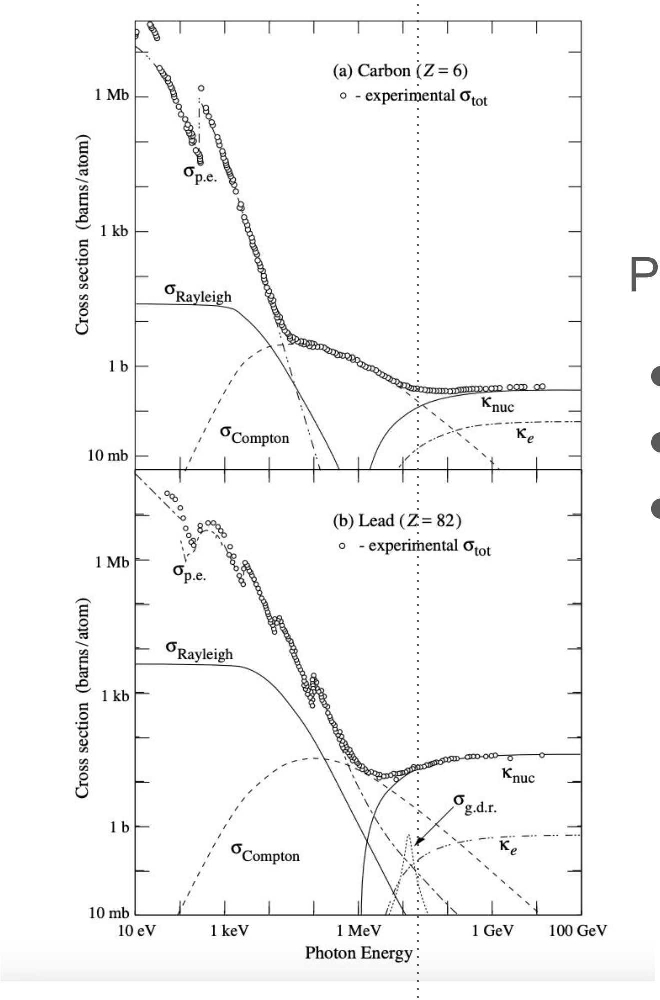
*Korchin, PrimEx at JLab*

- Can integrate over angles to obtain positron energy distribution:

$$\frac{d\sigma_A}{d\epsilon_+} = \int \frac{d^4\sigma_A}{d\epsilon_+ d\theta_- d\theta_+ d\phi}\, \mathrm{d}\theta_+\, \mathrm{d}\theta_-\, \mathrm{d}\phi \quad = Z^2 \frac{\alpha^3}{m_e^2\omega^3}[(\epsilon_+^2 + \epsilon_-^2)(\phi_1 - \frac{4}{3}\log Z - 4f) + \frac{2}{3}\epsilon_+\epsilon_-(\phi_2 - \frac{4}{3}\log Z - 4f)].$$

- (Triplet) Atomic field scattering:
  - Scales ~Z

$$\frac{d^4\sigma_e}{d\epsilon_+ d\theta_- d\theta_+ d\phi} = Z \frac{\alpha^3}{2\pi\omega^3\vec{Q}^4} H(\vec{Q}^2)|T|^2$$




## Photon Total Cross Section v. Energy

- at energies greater than ~1MeV, $\mathbf{K}_{nuc} > \mathbf{K}_{e}$
- At 30MeV, $\mathbf{K}_{nuc} > \mathbf{K}_{e}$ ~ *O(10)*
- for carbon, $\mathbf{K}_{nuc} \cong$ 300mb

*PDG, Particles Through Matter*

# Estimated positron signal rates using a 1μm C target:

- Bethe-Heitler is forward-peaked for relativistic electrons → use 20° spectrometer to measure positrons
  - angular acceptance approximately 3 msr

- Zeroth order: isotropic phase space ↔ $d\Omega = \Omega * (.003/4\pi)$
  - Total pair production cross section at 30MeV ≅300mb / 137 = $2*10^{-27}$ $cm^2$
  - Luminosity at 150μA = $9*10^{33}$ e-C $cm^{-2}s^{-1}$
  - Expect ≤ 4.3 kHz signal

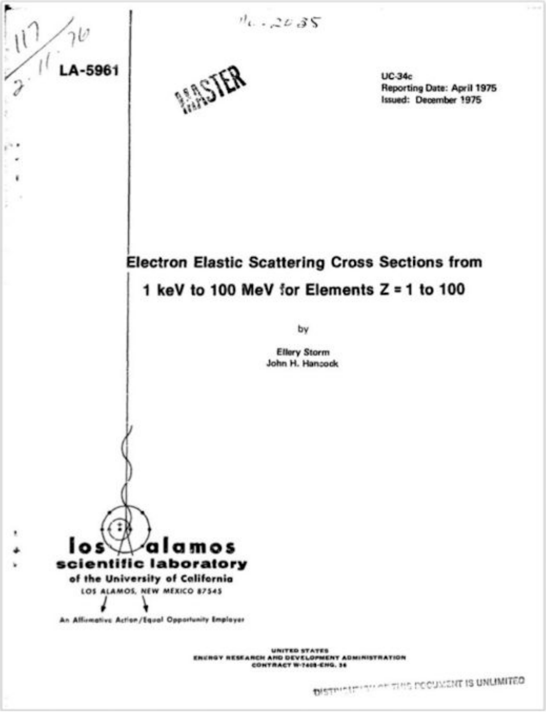
- First order: simulate 1E9 events in Mainz
  - Differential cross section ≅ $1.2*10^{-32}$ $cm^2$
  - Total signal rate within acceptance at 20° ≅ 130 Hz

# Checklist:

- Obtain more accurate Bethe-Heitler momentum and angular dependencies:
  - Possibly nontrivial screening corrections for the pair-production cross sections
  - Perform Geant simulations incorporating the actual DarkLight setup & geometry
- Quantify background processes:
  - Deflected electrons managing to reach the positron GEMs ? (from Cameron’s Monte Carlo)

# Estimating Electron Elastic Scattering

https://digital.library.unt.edu/ark:/67531/metadc865143/



LA-5961

MASTER

UC-34c
Reporting Date: April 1975
Issued: December 1975

Electron Elastic Scattering Cross Sections from
1 keV to 100 MeV for Elements Z = 1 to 100

by

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# Carbon

C ( 6 ) (BARNS/STERADIAN)

| DEG | 4.0E-01MEV RUTH | 4.0E-01MEV MOTT | 5.0E-01MEV RUTH | 5.0E-01MEV MOTT | 7.0E-01MEV RUTH | 7.0E-01MEV MOTT | 1.0E+00MEV RUTH | 1.0E+00MEV MOTT | 1.5E+00MEV RUTH | 1.5E+00MEV MOTT | 2.0E+00MEV RUTH | 2.0E+00MEV MOTT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.253E+07 | 8.266E+07 | 5.679E+07 | 5.687E+07 | 3.247E+07 | 3.253E+07 | 1.797E+07 | 1.800E+07 | 9.092E+06 | 9.107E+06 | 5.553E+06 | 5.563E+06 |
| 2 | 5.159E+06 | 5.171E+06 | 3.550E+06 | 3.558E+06 | 2.030E+06 | 2.035E+06 | 1.123E+06 | 1.126E+06 | 5.683E+05 | 5.698E+05 | 3.471E+05 | 3.480E+05 |
| 3 | 1.019E+06 | 1.022E+06 | 7.014E+05 | 7.035E+05 | 4.011E+05 | 4.024E+05 | 2.219E+05 | 2.226E+05 | 1.123E+05 | 1.127E+05 | 6.859E+04 | 6.882E+04 |
| 4 | 3.226E+05 | 3.238E+05 | 2.220E+05 | 2.228E+05 | 1.270E+05 | 1.274E+05 | 7.024E+04 | 7.051E+04 | 3.554E+04 | 3.568E+04 | 2.171E+04 | 2.180E+04 |
| 6 | 6.388E+04 | 6.408E+04 | 4.390E+04 | 4.409E+04 | 2.510E+04 | 2.522E+04 | 1.389E+04 | 1.395E+04 | 7.028E+03 | 7.061E+03 | 4.293E+03 | 4.313E+03 |
| 8 | 2.021E+04 | 2.031E+04 | 1.391E+04 | 1.398E+04 | 7.954E+03 | 7.993E+03 | 4.401E+03 | 4.422E+03 | 2.227E+03 | 2.238E+03 | 1.360E+03 | 1.367E+03 |
| 10 | 8.295E+03 | 8.334E+03 | 5.707E+03 | 5.734E+03 | 3.264E+03 | 3.279E+03 | 1.806E+03 | 1.814E+03 | 9.138E+02 | 9.178E+02 | 5.581E+02 | 5.605E+02 |
| 15 | 1.649E+03 | 1.653E+03 | 1.135E+03 | 1.137E+03 | 6.488E+02 | 6.496E+02 | 3.590E+02 | 3.592E+02 | 1.817E+02 | 1.817E+02 | 1.110E+02 | 1.110E+02 |
| 20 | 5.264E+02 | 5.249E+02 | 3.622E+02 | 3.607E+02 | 2.071E+02 | 2.060E+02 | 1.146E+02 | 1.138E+02 | 5.799E+01 | 5.754E+01 | 3.542E+01 | 3.513E+01 |
| 30 | 1.067E+02 | 1.043E+02 | 7.339E+01 | 7.154E+01 | 4.197E+01 | 4.074E+01 | 2.322E+01 | 2.246E+01 | 1.175E+01 | 1.134E+01 | 7.177E+00 | 6.916E+00 |
| 45 | 2.232E+01 | 2.074E+01 | 1.536E+01 | 1.415E+01 | 8.781E+00 | 8.006E+00 | 4.858E+00 | 4.390E+00 | 2.459E+00 | 2.206E+00 | 1.502E+00 | 1.343E+00 |
| 60 | 7.658E+00 | 6.587E+00 | 5.269E+00 | 4.460E+00 | 3.013E+00 | 2.497E+00 | 1.667E+00 | 1.357E+00 | 8.436E-01 | 6.769E-01 | 5.153E-01 | 4.107E-01 |
| 75 | 3.485E+00 | 2.705E+00 | 2.398E+00 | 1.812E+00 | 1.37[illegible]E+00 | 9.985E-01 | 7.587E-01 | 5.354E-01 | 3.839E-01 | 2.642E-01 | 2.345E-01 | 1.594E-01 |
| 90 | 1.915E+00 | 1.309E+00 | 1.317E+00 | 8.632E-01 | 7.533E-01 | 4.654E-01 | 4.168E-01 | 2.446E-01 | 2.109E-01 | 1.187E-01 | 1.288E-01 | 7.103E-02 |
| 120 | 8.509E-01 | 4.267E-01 | 5.855E-01 | 2.679E-01 | 3.348E-01 | 1.339E-01 | 1.852E-01 | 6.533E-02 | 9.374E-02 | 2.959E-02 | 5.725E-02 | 1.709E-02 |
| 150 | 5.498E-01 | 2.012E-01 | 3.783E-01 | 1.175E-01 | 2.163E-01 | 5.155E-02 | 1.197E-01 | 2.140E-02 | 6.057E-02 | 8.014E-03 | 3.700E-02 | 4.095E-03 |
| 179 | 4.787E-01 | 1.512E-01 | 3.294E-01 | 8.449E-02 | 1.884E-01 | 3.368E-02 | 1.042E-01 | 1.197E-02 | 5.274E-02 | 3.422E-03 | 3.221E-02 | 1.342E-03 |

| DEG | 3.0E+00MEV RUTH | 3.0E+00MEV MOTT | 4.0E+00MEV RUTH | 4.0E+00MEV MOTT | 5.0E+00MEV RUTH | 5.0E+00MEV MOTT | 7.0E+00MEV RUTH | 7.0E+00MEV MOTT | 1.0E+01MEV RUTH | 1.0E+01MEV MOTT | 1.5E+01MEV RUTH | 1.5E+01MEV MOTT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.724E+06 | 2.729E+06 | 1.623E+06 | 1.625E+06 | 1.078E+06 | 1.080E+06 | 5.756E+05 | 5.766E+05 | 2.926E+05 | 2.931E+05 | 1.340E+05 | 1.342E+05 |
| 2 | 1.703E+05 | 1.707E+05 | 1.014E+05 | 1.017E+05 | 6.738E+04 | 6.755E+04 | 3.598E+04 | 3.608E+04 | 1.829E+04 | 1.834E+04 | 8.378E+03 | 8.400E+03 |
| 3 | 3.365E+04 | 3.376E+04 | 2.004E+04 | 2.011E+04 | 1.331E+04 | 1.336E+04 | 7.110E+03 | 7.134E+03 | 3.614E+03 | 3.626E+03 | 1.655E+03 | 1.661E+03 |
| 4 | 1.065E+04 | 1.069E+04 | 6.343E+03 | 6.368E+03 | 4.214E+03 | 4.231E+03 | 2.250E+03 | 2.259E+03 | 1.144E+03 | 1.148E+03 | 5.239E+02 | 5.260E+02 |
| 6 | 2.106E+03 | 2.116E+03 | 1.254E+03 | 1.260E+03 | 8.331E+02 | 8.371E+02 | 4.450E+02 | 4.471E+02 | 2.262E+02 | 2.273E+02 | 1.036E+02 | 1.041E+02 |
| 8 | 6.672E+02 | 6.705E+02 | 3.974E+02 | 3.993E+02 | 2.640E+02 | 2.653E+02 | 1.410E+02 | 1.417E+02 | 7.167E+01 | 7.201E+01 | 3.283E+01 | 3.298E+01 |
| 10 | 2.738E+02 | 2.750E+02 | 1.631E+02 | 1.638E+02 | 1.083E+02 | 1.088E+02 | 5.785E+01 | 5.810E+01 | 2.941E+01 | 2.953E+01 | 1.347E+01 | 1.353E+01 |
| 15 | 5.443E+01 | 5.442E+01 | 3.242E+01 | 3.241E+01 | 2.153E+01 | 2.153E+01 | 1.150E+01 | 1.150E+01 | 5.846E+00 | 5.844E+00 | 2.678E+00 | 2.677E+00 |
| 20 | 1.738E+01 | 1.723E+01 | 1.035E+01 | 1.026E+01 | 6.874E+00 | 6.814E+00 | 3.671E+00 | 3.639E+00 | 1.866E+00 | 1.850E+00 | 8.548E-01 | 8.471E-01 |
| 30 | 3.521E+00 | 3.389E+00 | 2.097E+00 | 2.017E+00 | 1.393E+00 | 1.340E+00 | 7.439E-01 | 7.154E-01 | 3.781E-01 | 3.636E-01 | 1.732E-01 | 1.665E-01 |
| 45 | 7.366E-01 | 6.567E-01 | 4.387E-01 | 3.906E-01 | 2.914E-01 | 2.593E-01 | 1.557E-01 | 1.384E-01 | 7.912E-02 | 7.034E-02 | 3.624E-02 | 3.221E-02 |
| 60 | 2.528E-01 | 2.003E-01 | 1.505E-01 | 1.190E-01 | 1.000E-01 | 7.895E-02 | 5.341E-02 | 4.211E-02 | 2.715E-02 | 2.139E-02 | 1.244E-02 | 9.795E-03 |
| 75 | 1.158E-01 | 7.739E-02 | 6.851E-02 | 4.589E-02 | 4.551E-02 | 3.041E-02 | 2.431E-02 | 1.621E-02 | 1.236E-02 | 8.229E-03 | 5.659E-03 | 3.767E-03 |
| 90 | 6.319E-02 | 3.422E-02 | 3.764E-02 | 2.023E-02 | 2.500E-02 | 1.339E-02 | 1.335E-02 | 7.124E-03 | 6.787E-03 | 3.614E-03 | 3.109E-03 | 1.653E-03 |
| 120 | 2.809E-02 | 7.959E-03 | 1.673E-02 | 4.636E-03 | 1.111E-02 | 3.045E-03 | 5.935E-03 | 1.609E-03 | 3.017E-03 | 8.126E-04 | 1.382E-03 | 3.709E-04 |
| 150 | 1.815E-02 | 1.666E-03 | 1.081E-02 | 9.078E-04 | 7.180E-03 | 5.747E-04 | 3.835E-03 | 2.927E-04 | 1.949E-03 | 1.447E-04 | 8.928E-04 | 6.519E-05 |
| 179 | 1.580E-02 | 3.373E-04 | 9.411E-03 | 1.220E-04 | 6.252E-03 | 5.446E-05 | 3.339E-03 | 1.578E-05 | 1.697E-03 | 4.165E-06 | 7.773E-04 | 9.105E-07 |

| DEG | 2.0E+01MEV RUTH | 2.0E+01MEV MOTT | 3.0E+01MEV RUTH | 3.0E+01MEV MOTT | 4.0E+01MEV RUTH | 4.0E+01MEV MOTT | 5.0E+01MEV RUTH | 5.0E+01MEV MOTT | 7.0E+01MEV RUTH | 7.0E+01MEV MOTT | 1.0E+02MEV RUTH | 1.0E+02MEV MOTT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.657E+04 | 7.670E+04 | 3.458E+04 | 3.464E+04 | 1.961E+04 | 1.964E+04 | 1.261E+04 | 1.263E+04 | 6.472E+03 | 6.483E+03 | 3.185E+03 | 3.190E+03 |
| 2 | 4.787E+03 | 4.799E+03 | 2.162E+03 | 2.167E+03 | 1.226E+03 | 1.229E+03 | 7.885E+02 | 7.905E+02 | 4.046E+02 | 4.056E+02 | 1.991E+02 | 1.996E+02 |
| 3 | 9.457E+02 | 9.490E+02 | 4.271E+02 | 4.286E+02 | 2.422E+02 | 2.430E+02 | 1.558E+02 | 1.563E+02 | 7.993E+01 | 8.021E+01 | 3.934E+01 | 3.947E+01 |
| 4 | 2.993E+02 | 3.006E+02 | 1.352E+02 | 1.357E+02 | 7.666E+01 | 7.697E+01 | 4.931E+01 | 4.951E+01 | 2.530E+01 | 2.540E+01 | 1.245E+01 | 1.250E+01 |
| 6 | 5.919E+01 | 5.947E+01 | 2.673E+01 | 2.686E+01 | 1.516E+01 | 1.523E+01 | 9.750E+00 | 9.796E+00 | 5.003E+00 | 5.027E+00 | 2.462E+00 | 2.474E+00 |
| 8 | 1.875E+01 | 1.885E+01 | 8.470E+00 | 8.511E+00 | 4.803E+00 | 4.826E+00 | 3.089E+00 | 3.104E+00 | 1.585E+00 | 1.593E+00 | 7.801E-01 | 7.839E-01 |
| 10 | 7.696E+00 | 7.728E+00 | 3.476E+00 | 3.490E+00 | 1.971E+00 | 1.979E+00 | 1.268E+00 | 1.273E+00 | 6.505E-01 | 6.532E-01 | 3.201E-01 | 3.215E-01 |
| 15 | 1.530E+00 | 1.529E+00 | 6.909E-01 | 6.907E-01 | 3.918E-01 | 3.917E-01 | 2.520E-01 | 2.519E-01 | 1.293E-01 | 1.293E-01 | 6.363E-02 | 6.362E-02 |
| 20 | 4.884E-01 | 4.840E-01 | 2.206E-01 | 2.186E-01 | 1.251E-01 | 1.240E-01 | 8.045E-02 | 7.973E-02 | 4.128E-02 | 4.091E-02 | 2.031E-02 | 2.013E-02 |
| 30 | 9.696E-02 | 9.514E-02 | 4.469E-02 | 4.297E-02 | 2.534E-02 | 2.437E-02 | 1.630E-02 | 1.567E-02 | 8.364E-03 | 8.041E-03 | 4.116E-03 | 3.957E-03 |
| 45 | 2.071E-02 | 1.840E-02 | 9.351E-03 | 8.310E-03 | 5.303E-03 | 4.713E-03 | 3.411E-03 | 3.031E-03 | 1.750E-03 | 1.555E-03 | 8.612E-04 | 7.654E-04 |
| 60 | 7.105E-03 | 5.596E-03 | 3.209E-03 | 2.527E-03 | 1.820E-03 | 1.433E-03 | 1.170E-03 | 9.216E-04 | 6.005E-04 | 4.729E-04 | 2.955E-04 | 2.327E-04 |
| 75 | 3.233E-03 | 2.152E-03 | 1.460E-03 | 9.715E-04 | 8.281E-04 | 5.509E-04 | 5.326E-04 | 3.543E-04 | 2.733E-04 | 1.818E-04 | 1.345E-04 | 8.946E-05 |
| 90 | 1.776E-03 | 9.442E-04 | 8.022E-04 | 4.263E-04 | 4.549E-04 | 2.417E-04 | 2.926E-04 | 1.555E-04 | 1.501E-04 | 7.976E-05 | 7.388E-05 | 3.925E-05 |
| 120 | 7.894E-04 | 2.116E-04 | 3.565E-04 | 9.548E-05 | 2.022E-04 | 5.413E-05 | 1.300E-04 | 3.401E-05 | 6.673E-05 | 1.786E-05 | 3.286E-05 | 8.788E-06 |
| 150 | 5.101E-04 | 3.702E-05 | 2.304E-04 | 1.665E-05 | 1.306E-04 | 9.456E-06 | 8.403E-05 | 6.058E-06 | 4.312E-05 | 3.106E-06 | 2.122E-05 | 1.528E-06 |
| 179 | 4.441E-04 | 3.131E-07 | 2.006E-04 | 7.291E-08 | 1.137E-04 | 2.749E-08 | 7.316E-05 | 1.351E-08 | 3.754E-05 | 5.055E-09 | 1.847E-05 | 1.993E-09 |

# Carbon

C ( 6 ) (BARNS/STERADIAN)

| DEG | 4.0E-01MEV RUTH | 4.0E-01MEV MOTT | 5.0E-01MEV RUTH | 5.0E-01MEV MOTT | 7.0E-01MEV RUTH | 7.0E-01MEV MOTT | 1.0E+00MEV RUTH | 1.0E+00MEV MOTT | 1.5E+00MEV RUTH | 1.5E+00MEV MOTT | 2.0E+00MEV RUTH | 2.0E+00MEV MOTT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.253E+07 | 8.266E+07 | 5.679E+07 | 5.687E+07 | 3.247E+07 | 3.253E+07 | 1.797E+07 | 1.800E+07 | 9.092E+06 | 9.107E+06 | 5.553E+06 | 5.563E+06 |
| 2 | 5.159E+06 | 5.171E+06 | 3.550E+06 | 3.558E+06 | 2.030E+06 | 2.035E+06 | 1.123E+06 | 1.126E+06 | 5.683E+05 | 5.698E+05 | 3.471E+05 | 3.480E+05 |
| 3 | 1.019E+06 | 1.022E+06 | 7.014E+05 | 7.035E+05 | 4.011E+05 | 4.024E+05 | 2.219E+05 | 2.226E+05 | 1.123E+05 | 1.127E+05 | 6.859E+04 | 6.882E+04 |
| 4 | 3.226E+05 | 3.238E+05 | 2.220E+05 | 2.228E+05 | 1.270E+05 | 1.274E+05 | 7.024E+04 | 7.051E+04 | 3.554E+04 | 3.568E+04 | 2.171E+04 | 2.180E+04 |
| 6 | 6.380E+04 | 6.408E+04 | 4.390E+04 | 4.409E+04 | 2.510E+04 | 2.522E+04 | 1.389E+04 | 1.395E+04 | 7.028E+03 | 7.061E+03 | 4.293E+03 | 4.313E+03 |
| 8 | 2.021E+04 | 2.031E+04 | 1.391E+04 | 1.398E+04 | 7.954E+03 | 7.993E+03 | 4.401E+03 | 4.422E+03 | 2.227E+03 | 2.238E+03 | 1.360E+03 | 1.367E+03 |
| 10 | 8.295E+03 | 8.334E+03 | 5.707E+03 | 5.734E+03 | 3.264E+03 | 3.279E+03 | 1.806E+03 | 1.814E+03 | 9.138E+02 | 9.178E+02 | 5.581E+02 | 5.605E+02 |
| 15 | 1.649E+03 | 1.653E+03 | 1.135E+03 | 1.137E+03 | 6.488E+02 | 6.496E+02 | 3.590E+02 | 3.592E+02 | 1.817E+02 | 1.817E+02 | 1.110E+02 | 1.110E+02 |
| 20 | 5.264E+02 | 5.249E+02 | 3.622E+02 | 3.607E+02 | 2.071E+02 | 2.060E+02 | 1.146E+02 | 1.138E+02 | 5.799E+01 | 5.754E+01 | 3.542E+01 | 3.513E+01 |
| 30 | 1.067E+02 | 1.043E+02 | 7.339E+01 | 7.154E+01 | 4.197E+01 | 4.074E+01 | 2.322E+01 | 2.246E+01 | 1.175E+01 | 1.134E+01 | 7.177E+00 | 6.916E+00 |
| 45 | 2.232E+01 | 2.074E+01 | 1.536E+01 | 1.415E+01 | 8.781E+00 | 8.006E+00 | 4.858E+00 | 4.390E+00 | 2.459E+00 | 2.206E+00 | 1.502E+00 | 1.343E+00 |
| 60 | 7.658E+00 | 6.587E+00 | 5.269E+00 | 4.460E+00 | 3.013E+00 | 2.497E+00 | 1.667E+00 | 1.357E+00 | 8.436E-01 | 6.769E-01 | 5.153E-01 | 4.107E-01 |
| 75 | 3.485E+00 | 2.705E+00 | 2.398E+00 | 1.812E+00 | 1.37[illegible]E+00 | 9.985E-01 | 7.587E-01 | 5.354E-01 | 3.839E-01 | 2.642E-01 | 2.345E-01 | 1.594E-01 |
| 90 | 1.915E+00 | 1.309E+00 | 1.317E+00 | 8.632E-01 | 7.533E-01 | 4.654E-01 | 4.168E-01 | 2.446E-01 | 2.109E-01 | 1.187E-01 | 1.288E-01 | 7.103E-02 |
| 120 | 8.509E-01 | 4.267E-01 | 5.855E-01 | 2.679E-01 | 3.348E-01 | 1.339E-01 | 1.852E-01 | 6.533E-02 | 9.374E-02 | 2.959E-02 | 5.725E-02 | 1.709E-02 |
| 150 | 5.498E-01 | 2.012E-01 | 3.783E-01 | 1.175E-01 | 2.163E-01 | 5.155E-02 | 1.197E-01 | 2.140E-02 | 6.057E-02 | 8.014E-03 | 3.700E-02 | 4.095E-03 |
| 179 | 4.787E-01 | 1.512E-01 | 3.294E-01 | 8.449E-02 | 1.884E-01 | 3.368E-02 | 1.042E-01 | 1.197E-02 | 5.274E-02 | 3.422E-03 | 3.221E-02 | 1.342E-03 |

| DEG | 3.0E+00MEV RUTH | 3.0E+00MEV MOTT | 4.0E+00MEV RUTH | 4.0E+00MEV MOTT | 5.0E+00MEV RUTH | 5.0E+00MEV MOTT | 7.0E+00MEV RUTH | 7.0E+00MEV MOTT | 1.0E+01MEV RUTH | 1.0E+01MEV MOTT | 1.5E+01MEV RUTH | 1.5E+01MEV MOTT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.724E+06 | 2.729E+06 | 1.623E+06 | 1.625E+06 | 1.078E+06 | 1.080E+06 | 5.756E+05 | 5.766E+05 | 2.926E+05 | 2.931E+05 | 1.340E+05 | 1.342E+05 |
| 2 | 1.703E+05 | 1.707E+05 | 1.014E+05 | 1.017E+05 | 6.738E+04 | 6.755E+04 | 3.598E+04 | 3.608E+04 | 1.829E+04 | 1.834E+04 | 8.378E+03 | 8.400E+03 |
| 3 | 3.365E+04 | 3.376E+04 | 2.004E+04 | 2.011E+04 | 1.331E+04 | 1.336E+04 | 7.110E+03 | 7.134E+03 | 3.614E+03 | 3.626E+03 | 1.655E+03 | 1.661E+03 |
| 4 | 1.065E+04 | 1.069E+04 | 6.343E+03 | 6.368E+03 | 4.214E+03 | 4.231E+03 | 2.250E+03 | 2.259E+03 | 1.144E+03 | 1.148E+03 | 5.239E+02 | 5.260E+02 |
| 6 | 2.106E+03 | 2.116E+03 | 1.254E+03 | 1.260E+03 | 8.331E+02 | 8.371E+02 | 4.450E+02 | 4.471E+02 | 2.262E+02 | 2.273E+02 | 1.036E+02 | 1.041E+02 |
| 8 | 6.672E+02 | 6.705E+02 | 3.974E+02 | 3.993E+02 | 2.640E+02 | 2.653E+02 | 1.410E+02 | 1.417E+02 | 7.167E+01 | 7.201E+01 | 3.283E+01 | 3.298E+01 |
| 10 | 2.738E+02 | 2.750E+02 | 1.631E+02 | 1.638E+02 | 1.083E+02 | 1.088E+02 | 5.785E+01 | 5.810E+01 | 2.941E+01 | 2.953E+01 | 1.347E+01 | 1.353E+01 |
| 15 | 5.443E+01 | 5.442E+01 | 3.242E+01 | 3.241E+01 | 2.153E+01 | 2.153E+01 | 1.150E+01 | 1.150E+01 | 5.846E+00 | 5.844E+00 | 2.678E+00 | 2.677E+00 |
| 20 | 1.738E+01 | 1.723E+01 | 1.035E+01 | 1.026E+01 | 6.874E+00 | 6.814E+00 | 3.671E+00 | 3.639E+00 | 1.866E+00 | 1.850E+00 | 8.548E-01 | 8.471E-01 |
| 30 | 3.521E+00 | 3.389E+00 | 2.097E+00 | 2.017E+00 | 1.393E+00 | 1.340E+00 | 7.439E-01 | 7.154E-01 | 3.781E-01 | 3.636E-01 | 1.732E-01 | 1.665E-01 |
| 45 | 7.366E-01 | 6.567E-01 | 4.387E-01 | 3.906E-01 | 2.914E-01 | 2.593E-01 | 1.557E-01 | 1.384E-01 | 7.912E-02 | 7.034E-02 | 3.624E-02 | 3.221E-02 |
| 60 | 2.528E-01 | 2.003E-01 | 1.505E-01 | 1.190E-01 | 1.000E-01 | 7.895E-02 | 5.341E-02 | 4.211E-02 | 2.715E-02 | 2.139E-02 | 1.244E-02 | 9.795E-03 |
| 75 | 1.158E-01 | 7.739E-02 | 6.851E-02 | 4.589E-02 | 4.551E-02 | 3.041E-02 | 2.431E-02 | 1.621E-02 | 1.236E-02 | 8.229E-03 | 5.659E-03 | 3.767E-03 |
| 90 | 6.318E-02 | 3.422E-02 | 3.764E-02 | 2.023E-02 | 2.500E-02 | 1.339E-02 | 1.335E-02 | 7.124E-03 | 6.787E-03 | 3.614E-03 | 3.109E-03 | 1.653E-03 |
| 120 | 2.809E-02 | 7.959E-03 | 1.673E-02 | 4.636E-03 | 1.111E-02 | 3.045E-03 | 5.935E-03 | 1.609E-03 | 3.017E-03 | 8.126E-04 | 1.382E-03 | 3.709E-04 |
| 150 | 1.815E-02 | 1.666E-03 | 1.081E-02 | 9.078E-04 | 7.180E-03 | 5.747E-04 | 3.835E-03 | 2.927E-04 | 1.949E-03 | 1.447E-04 | 8.928E-04 | 6.519E-05 |
| 179 | 1.580E-02 | 3.373E-04 | 9.411E-03 | 1.220E-04 | 6.252E-03 | 5.446E-05 | 3.339E-03 | 1.578E-05 | 1.697E-03 | 4.165E-06 | 7.773E-04 | 9.105E-07 |

| DEG | 2.0E+01MEV RUTH | 2.0E+01MEV MOTT | 3.0E+01MEV RUTH | 3.0E+01MEV MOTT | 4.0E+01MEV RUTH | 4.0E+01MEV MOTT | 5.0E+01MEV RUTH | 5.0E+01MEV MOTT | 7.0E+01MEV RUTH | 7.0E+01MEV MOTT | 1.0E+02MEV RUTH | 1.0E+02MEV MOTT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.657E+04 | 7.670E+04 | 3.458E+04 | 3.464E+04 | 1.961E+04 | 1.964E+04 | 1.261E+04 | 1.263E+04 | 6.472E+03 | 6.483E+03 | 3.185E+03 | 3.190E+03 |
| 2 | 4.787E+03 | 4.799E+03 | 2.162E+03 | 2.167E+03 | 1.226E+03 | 1.229E+03 | 7.885E+02 | 7.905E+02 | 4.046E+02 | 4.056E+02 | 1.991E+02 | 1.996E+02 |
| 3 | 9.457E+02 | 9.490E+02 | 4.271E+02 | 4.286E+02 | 2.422E+02 | 2.430E+02 | 1.558E+02 | 1.563E+02 | 7.993E+01 | 8.021E+01 | 3.934E+01 | 3.947E+01 |
| 4 | 2.993E+02 | 3.006E+02 | 1.352E+02 | 1.357E+02 | 7.666E+01 | 7.697E+01 | 4.931E+01 | 4.951E+01 | 2.530E+01 | 2.540E+01 | 1.245E+01 | 1.250E+01 |
| 6 | 5.919E+01 | 5.947E+01 | 2.673E+01 | 2.686E+01 | 1.516E+01 | 1.523E+01 | 9.750E+00 | 9.796E+00 | 5.003E+00 | 5.027E+00 | 2.462E+00 | 2.474E+00 |
| 8 | 1.875E+01 | 1.885E+01 | 8.470E+00 | 8.511E+00 | 4.803E+00 | 4.826E+00 | 3.089E+00 | 3.104E+00 | 1.585E+00 | 1.593E+00 | 7.801E-01 | 7.839E-01 |
| 10 | 7.696E+00 | 7.728E+00 | 3.476E+00 | 3.490E+00 | 1.971E+00 | 1.979E+00 | 1.268E+00 | 1.273E+00 | 6.505E-01 | 6.532E-01 | 3.201E-01 | 3.215E-01 |
| 15 | 1.530E+00 | 1.529E+00 | 6.909E-01 | 6.907E-01 | 3.918E-01 | 3.917E-01 | 2.520E-01 | 2.519E-01 | 1.293E-01 | 1.293E-01 | 6.363E-02 | 6.362E-02 |
| 20 | 4.884E-01 | 4.840E-01 | 2.206E-01 | 2.186E-01 | 1.251E-01 | 1.240E-01 | 8.045E-02 | 7.973E-02 | 4.128E-02 | 4.091E-02 | 2.031E-02 | 2.013E-02 |
| 30 | 9.696E-02 | 9.514E-02 | 4.469E-02 | 4.297E-02 | 2.534E-02 | 2.437E-02 | 1.630E-02 | 1.567E-02 | 8.364E-03 | 8.041E-03 | 4.116E-03 | 3.957E-03 |
| 45 | 2.071E-02 | 1.840E-02 | 9.351E-03 | 8.310E-03 | 5.303E-03 | 4.713E-03 | 3.411E-03 | 3.031E-03 | 1.750E-03 | 1.555E-03 | 8.612E-04 | 7.654E-04 |
| 60 | 7.105E-03 | 5.596E-03 | 3.209E-03 | 2.527E-03 | 1.820E-03 | 1.433E-03 | 1.170E-03 | 9.216E-04 | 6.005E-04 | 4.729E-04 | 2.955E-04 | 2.327E-04 |
| 75 | 3.233E-03 | 2.152E-03 | 1.460E-03 | 9.715E-04 | 8.281E-04 | 5.509E-04 | 5.326E-04 | 3.543E-04 | 2.733E-04 | 1.818E-04 | 1.345E-04 | 8.946E-05 |
| 90 | 1.776E-03 | 9.442E-04 | 8.022E-04 | 4.263E-04 | 4.549E-04 | 2.417E-04 | 2.926E-04 | 1.555E-04 | 1.501E-04 | 7.976E-05 | 7.388E-05 | 3.925E-05 |
| 120 | 7.894E-04 | 2.116E-04 | 3.565E-04 | 9.548E-05 | 2.022E-04 | 5.413E-05 | 1.300E-04 | 3.481E-05 | 6.673E-05 | 1.786E-05 | 3.286E-05 | 8.788E-06 |
| 150 | 5.101E-04 | 3.702E-05 | 2.304E-04 | 1.665E-05 | 1.306E-04 | 9.456E-06 | 8.403E-05 | 6.058E-06 | 4.312E-05 | 3.106E-06 | 2.122E-05 | 1.528E-06 |
| 179 | 4.441E-04 | 3.131E-07 | 2.006E-04 | 7.291E-08 | 1.137E-04 | 2.749E-08 | 7.316E-05 | 1.351E-08 | 3.754E-05 | 5.055E-09 | 1.847E-05 | 1.993E-09 |

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# Rate Estimate (Carbon)

- $E_0 = 30$ MeV
- Scattering angle = $30^o$
- Differential cross section = $6.2 \times 10^{-2}$ barns/steradian = $6.2 \times 10^{-26}$ $cm^2$/sr
- Electron current = $9 \times 10^{14}$ electrons/sec (150 microamps)
- 1 micron thick C foil = 0.22 $mg/cm^2$ = $0.22 \times 6 \times 10^{20}/12$ Ta-atoms/$cm^2$= $1 \times 10^{19}$ C-atoms/$cm^2$
- Luminosity = $9 \times 10^{14} \times 1 \times 10^{19}$ e-C/$cm^2$/s = $9 \times 10^{33}$ e-C/$cm^2$/s
- Elastic scattering rate = $6.2 \times 10^{-26} \times 9 \times 10^{33}$ /s/sr = $5 \times 10^{8}$ Hz/sr
- For solid angle of 3 msr, elastic rate is 1.5 MHz.

# Rate Estimate (Tantalum)

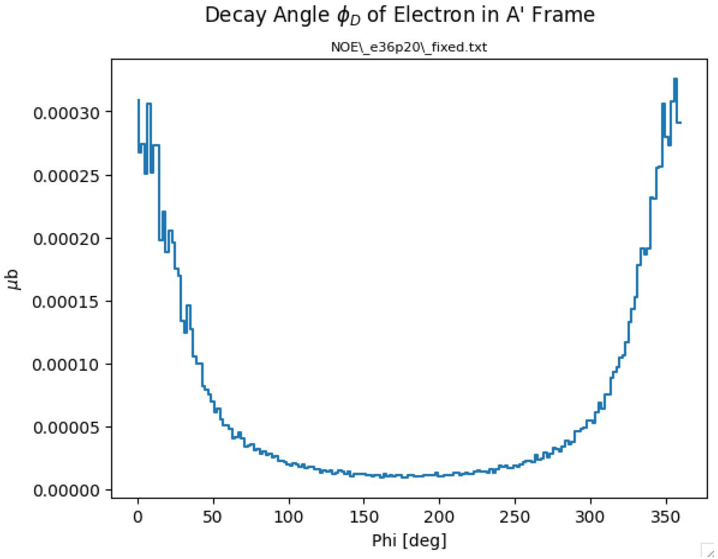
- $E_0$ = 30 MeV
- Scattering angle = 30$^{o}$
- Differential cross section = 8.9 barns/steradian = 8.9 x 10$^{-24}$ cm$^2$/sr
- Electron current = 9 x 10$^{14}$ electrons/sec (150 microamps)
- 1 micron thick Ta foil = 1.67 mg/cm$^2$ = 1.67 x 6 x 10$^{20}$/181 Ta-atoms/cm$^2$= 5.5 x 10$^{18}$ Ta-atoms/cm$^2$
- Luminosity = 9 x 10$^{14}$ x 5.5 x 10$^{18}$ e-Ta/cm$^2$/s = 5 x 10$^{33}$ e-Ta/cm$^2$/s
- Elastic scattering rate = 8.9 x 10$^{-24}$ x 5 x 10$^{33}$ /s/sr = 5 x 10$^{10}$ Hz/sr
- For solid angle of 3 msr, elastic rate is 150 MHz.

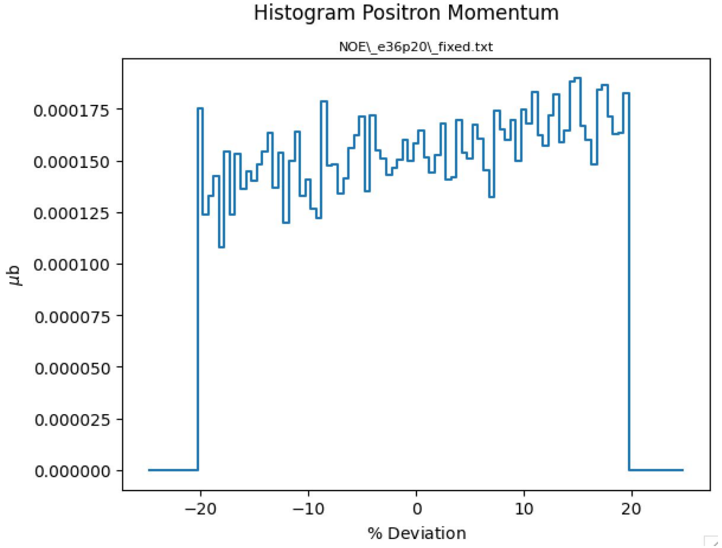
# Rate Estimate (Carbon)

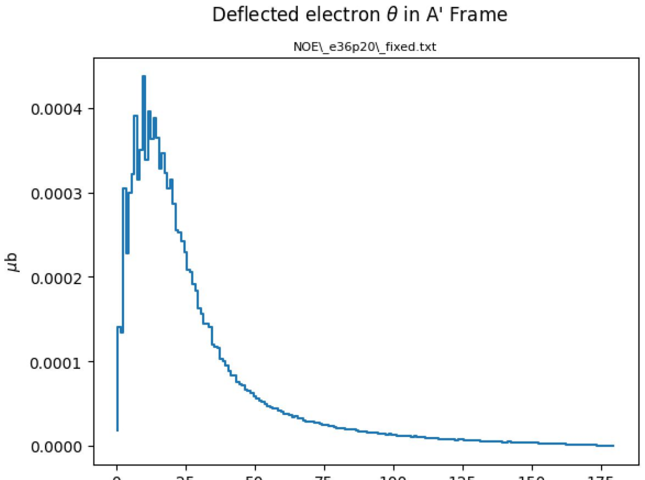
- $E_0 = 30$ MeV
- Scattering angle = $45^{o}$
- Differential cross section = $8.3 \times 10^{-3}$ barns/steradian = $8.3 \times 10^{-27}$ $cm^2/sr$
- Electron current = $9 \times 10^{14}$ electrons/sec (150 microamps)
- 1 micron thick C foil = 0.22 $mg/cm^2$ = $0.22 \times 6 \times 10^{20}/12$ C-atoms/$cm^2$ = $1 \times 10^{19}$ C-atoms/$cm^2$
- Luminosity = $9 \times 10^{14} \times 1 \times 10^{19}$ e-C/$cm^2$/s = $9 \times 10^{33}$ e-C/$cm^2$/s
- Elastic scattering rate = $8.3 \times 10^{-27} \times 9 \times 10^{33}$ /s/sr = $7.4 \times 10^{7}$ Hz/sr
- For solid angle of 3 msr, elastic rate is 0.2 MHz.

# Rate Estimate (Tantalum)

- $E_0 = 30$ MeV
- Scattering angle = $45^o$
- Differential cross section = 2.2 barns/steradian = $2.2 \times 10^{-24}$ $cm^2$/sr
- Electron current = $9 \times 10^{14}$ electrons/sec (150 microamps)
- 1 micron thick Ta foil = 1.67 mg/$cm^2$ = $1.67 \times 6 \times 10^{20}/181$ Ta-atoms/$cm^2$ = $5.5 \times 10^{18}$ Ta-atoms/$cm^2$
- Luminosity = $9 \times 10^{14} \times 5.5 \times 10^{18}$ e-Ta/$cm^2$/s = $5 \times 10^{33}$ e-Ta/$cm^2$/s
- Elastic scattering rate = $2.2 \times 10^{-24} \times 5 \times 10^{33}$ /s/sr = $1.2 \times 10^{10}$ Hz/sr
- For solid angle of 3 msr, elastic rate is 36 MHz.


Decay Angle $\phi_D$ of Electron in A' Frame
NOE_e36p20_fixed.txt
μb
0.00000
0.00005
0.00010
0.00015
0.00020
0.00025
0.00030
0
50
100
150
200
250
300
350
Phi [deg]


Histogram Positron Momentum
NOE_e36p20_fixed.txt
μb
0.000000
0.000025
0.000050
0.000075
0.000100
0.000125
0.000150
0.000175
−20
−10
0
10
20
% Deviation


Deflected electron $\theta$ in A' Frame
NOE_e36p20_fixed.txt
μb
0.0000
0.0001
0.0002
0.0003
0.0004