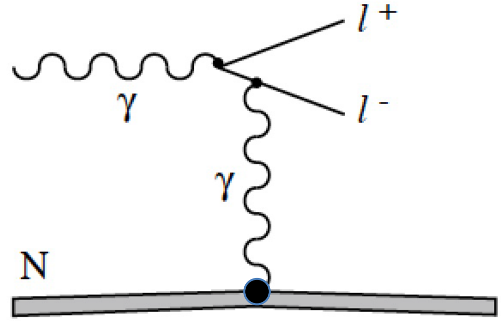
Sensitivity of the Bethe-Heitler cross section to the nuclear RMS charge radius



F(t)

$$\frac{d\sigma_B^c}{dx\, d\Omega_1\, d\Omega_2} = \frac{2\alpha^3 Z^2 \omega^4 x^2 (1-x)^2}{\pi^2 (\vec{q}^2)^2} \times \left[W_{\rm unp} + P_\gamma W_{\rm pol} \cos(2\phi)\right]$$

$$\times \left| F_{nuclear}\left(\vec{q}^2\right) - F_{atomic}\left(\vec{q}^2\right)\right|^2$$

$$W_{\rm unp} = \left[x^2 + (1-x)^2\right] |\vec{J}_T|^2 + m^2 |J_S|^2; \qquad W_{\rm pol} = -2x(1-x)|\vec{J}_T|^2.$$

with

$$J_S = \frac{1}{\vec{p}_1^2 + m^2} - \frac{1}{\vec{p}_2^2 + m^2} \qquad \vec{J}_T = \frac{\vec{p}_1}{\vec{p}_1^2 + m^2} + \frac{\vec{p}_2}{\vec{p}_2^2 + m^2}$$

Run the Bethe-Heitler event generator for two form factor choices:

1. Standard dipole form factor, modified to give the correct electronic rms proton charge radius:

$$F(Q^2)_{nuclear} = 1 - \frac{1}{6}\frac{< r^2 >}{\hbar c^2}Q^2 + O\left(Q^4\right)$$

$$F(Q^2)_{nuclear} = \frac{1}{\left(1+\frac{Q^2}{.71GeV^2}\right)^2} + 2\frac{Q^2}{.71GeV^2} - \frac{1}{6}\frac{< r^2 >}{\hbar c^2}Q^2$$

2. Form factor for point particle:

$$F(Q^2)_{nuclear} = 1$$

Run the event generator, bin events as a function of t:

2M events for $F(Q^2)_{F=dipole}$

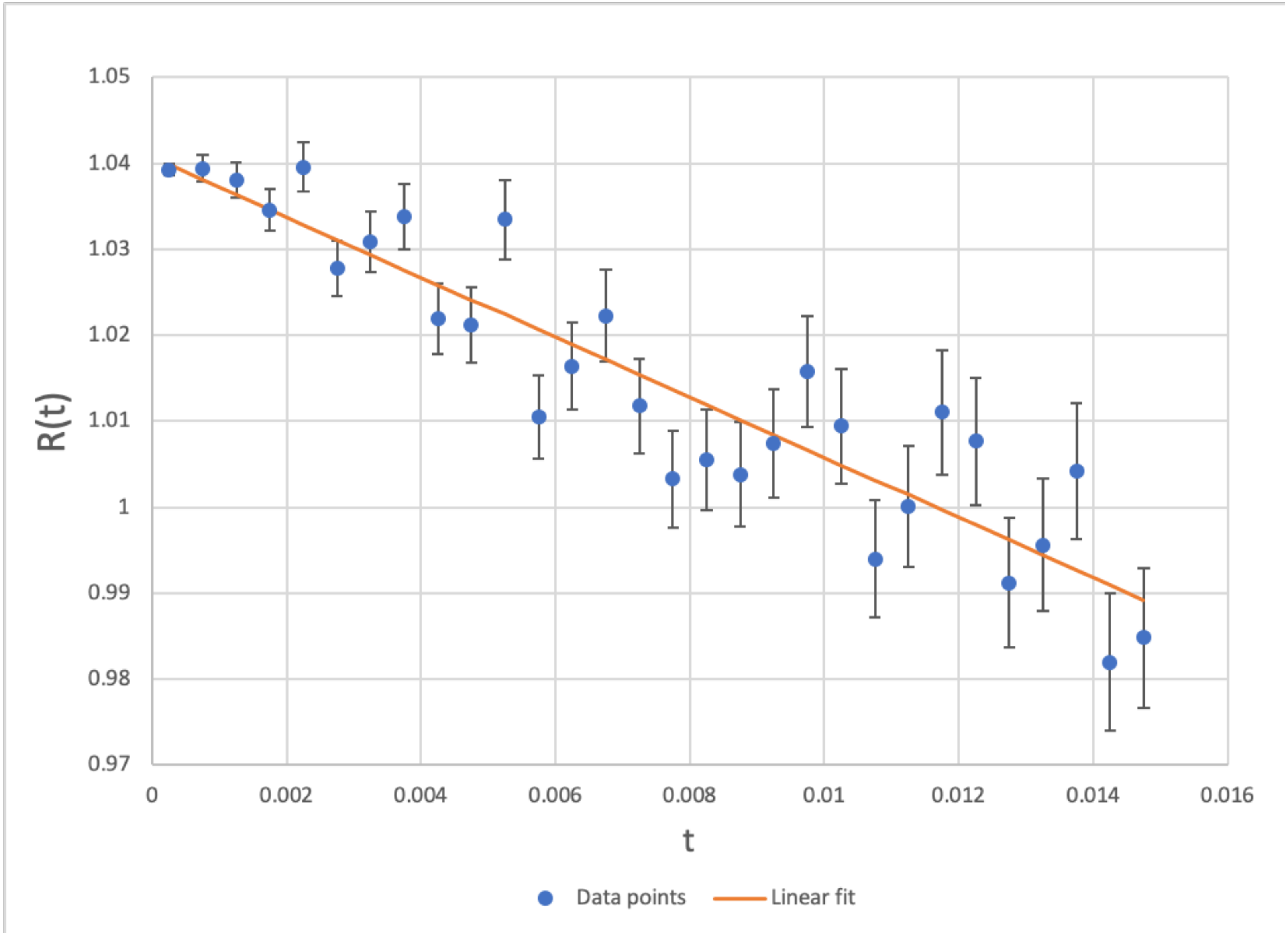
4M events for $F(Q^2)_{F=1}$

Require $W > 0.2$ GeV, and $\theta > 0.9^o$

Square root of ratio of yields:

$$R(t) = \sqrt{\frac{N(t)_{F=dipole}}{N(t)_{F=1}}} = C\left(1 - \frac{1}{6}\frac{< r^2 >}{\hbar c^2}t + O(t^2)\right)$$

Do a linear fit on R(t), varying C and $<r^2>$. Orders $O(t^2)$and higher are neglected in this fit.



1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
R(t)
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
t
Data points
Linear fit

Electronic RMS proton charge radius used in event generation: $\sqrt{<r^2>} = .879\ fm$

Result from the fit: $\sqrt{<r^2>} = .884 \pm .020\ fm$

$$\frac{\sqrt{<r^2>}_{electronic} - \sqrt{<r^2>}_{muonic}}{\sigma_{fit}} = \frac{.879 - .8409}{.020} \approx 2\sigma_{fit}$$

Improvements in the toy model:

1. Run event generator to increase statistics in $N(t)_{F=1}$ and $N(t)_{F=dipole}$

2. Adjust t-bin widths so they are consistent with resolution

3. Use a more realistic model for fitting:

$$\sqrt{\frac{N(t)_{F=dipole}}{N(t)_{F=1}}} = C\left(\frac{1}{\left(1+\frac{t}{.71GeV^2}\right)^2} + 2\frac{t}{.71GeV^2} - \frac{1}{6}\frac{<r^2>}{\hbar c^2}t - F(t)_{atomic}\right)\left(1-F(t)_{atomic}\right)^{-1}$$

Fit C and $<r^2>$

Analysis of real data:

1. Run the event generator to get high statistics in $N(t)_{F=1}$. Should have $N(t)_{F=1}$ >> $N(t)_{data}$

2. Apply realistic fiducial cuts for e^+e^- events. Want N_{data} >> 2M

3. Find some way to calibrate and test the MC calculation of the shape of the t-acceptance distribution, $\epsilon(t)$.